DOCUMENT RESUME

ED 132 539		CS 003 098

AUTHOR	Thorson, Esther L.
TITLE	A Profile of Children's Reading Abilities as Indexed in Five Perceptual Processing Experiments. Final Report.
INSTITUTION	Denison Univ., Granville, Ohio.
SPONS AGENCY	National Inst. of Education (DHEW), Washington, D.C. Office of Research Grants.
REPORT NO	5-0193
PUB DATE	31 Mar 75
GRANT	NE-G-00-3-0127
NOTE	126p.
EDRS PRICE	MF-$0.83 HC-$7.35 Plus Postage.
DESCRIPTORS	Failure Factors; *Perceptual Development; Primary Education; *Reaction Time; *Reading Difficulty; *Reading Processes; *Reading Research; Sensory Integration; *Visual Discrimination

ABSTRACT

Six separate experiments were undertaken to test the hypothesis that poor readers in first, second, and third grade would have more difficulty with simple perceptual discriminations than would good readers in the same grades. Various tasks were used in the experiments, including discrimination of line orientations, checking letters in three-letter words against a fourth letter, discrimination of letter pairs occurring in various contexts, auditory-visual integration, and letter matching and word-to-picture matching under different cueing conditions. Results in general indicated that differences between good and poor readers at these grades lie in the reaction times required to perform the discriminations, and sometimes the patterns across various tasks, rather than in error rates. It was hypothesized that proficient processing reaches an asymptotically equal reaction time for simple, well-rehearsed discriminations, but that poor readers even by third grade have not reached this level. (Author/AA)

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FINAL REPORT

PROJECT NO. 5-0193
GRANT NO. NE-G-00-3-0127

A PROFILE OF CHILDREN'S READING ABILITIES AS INDEXED IN FIVE PERCEPTUAL PROCESSING EXPERIMENTS

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MARCH 31, 1975

The research reported herein was performed pursuant to a grant with the National Institute of Education, U.S. Department of Health, Education and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official National Institute of Education position or policy.

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Abstract

The six experiments reported here are aimed at demonstrating in children from Grades 1, 2, and 3 that those designated by their teachers as being "poor" readers show considerably more difficulty with simple perceptual discriminations than do "good" readers. This greater difficulty is not reflected in differences between the two groups in their error rates, but rather in the general level, and sometimes the patterns across various tasks, of the reaction times required to perform the discriminations.

Experiment 1 examined reaction times in three tasks where line orientations were to be discriminated. First, second, and third grade good, medium, and poor readers were compared to college-level readers on the tasks. For the children, task and grade produced significant main effects, but reading level did not. Task produced a significant main effect for college-level readers. The pattern of latencies acorss the three line-discrimination tasks was not clear, although the task requiring discrimination of two lines slanted to the right at two different angles was most difficult for all subjects.

Experiment 2 compared the reaction times of good and poor readers to a three-letter word and its component letters in a paradigm which required checking each letter against a "catch" letter. Poor readers were significantly slower than good readers, and there were also main effects for grade and task. Two simple processing models' predictions were compared to the observed reaction times, and it was concluded that both good and poor readers show, with increase in grade, reaction times increasingly close to those predicted by the model hypothesizing parallel processing of the letters when grouped into a word.

Experiment 3 compared good and poor readers', again from Grades 1, 2, and 3, reaction times to discriminate letter pairs occurring either by themselves (a), in the context of a word (b), or in a word appearing in a phrase (c). In view of the difficulty first grade poor readers showed with the three-letter word in Experiment 2, it was hypothesized in Experiment 3 that first grade poor readers would show long reaction times when the letters appeared in contexts (b) and (c), but that no other children would show similar "context inhibition." On the three letter-pairs tested, both first grade good and first grade poor readers showed context inhibition. Overall, poor readers were slower than good readers. In the analysis pooling reaction times across the three letter-pairs, only first grade poor readers showed context inhibition.

Experiment 4 compared the reaction times of good and poor readers to a simple auditory-visual integration task, in which a button press was required if the letter presented auditorily matched that presented visually. Although error rates for good and poor readers were approximately equal, poor readers were much slower than good readers, and the differences, in fact, in the two groups increased across grade. In addition, both second and third grade poor readers were slower on this simplest of tasks than were first grade poor readers.

Experiment 5 compared first through third grade good and poor readers' reaction times to match letters and to match a line drawing with a word when cued correctly for the tasks, and when cued for one of the tasks, but presented with the other. There were significant main effects for reading level, grade, and task, and a significant interaction between task and reading level. Poor readers were only slightly slower than good readers on the letter-matching tasks, but much slower than good readers on the word-picture matching task. The differences were greatest between first grade good and poor readers.

Experiment 6 was a replication and expansion of Experiment 1. Five additional line-orientation pairs were added to the original three in order to further compare relative difficulty of discriminating horizontal, vertical, and slanted lines. First through third grade good and poor readers and college-level readers were compared. College-level readers showed much smaller latencies than good readers, and good readers were faster than poor readers. In comparing latencies across the tasks, good readers and college-level readers tended to show fairly equal latencies, except in the task requiring discrimination between two lines slanted in the same direction at slightly different slopes. (This task also produced the slowest reaction times in Experiment 1.) Poor readers, on the other hand, showed large and variable differences in latencies across the eight tasks. It was hypothesized that the latter difference lends support to the hypothesis that proficient processing reaches an asymptotically equal reaction time for simple, well-rehearsed discriminations, but that poor readers even by third grade are far from reaching this level.

Introduction to the Experiments

The experiments reported here were designed for two general purposes. One was to demonstrate that there are significant differences in the way good and poor readers process simple perceptual discriminations. It was expected that these differences would be reflected in the fact that the perceptual tasks presented to the children would be differentially difficult for them, depending upon whether they were good or poor readers. The differences were hypothesized to be other than just those wherein third grade poor readers show different reaction time patterns from third grade good readers but that these patterns are the same as those shown by first grade good readers. The latter finding would support a "developmental lag" hypothesis without giving any indication that poor readers were learning any different processing procedures than good readers. Only in Experiment 6 was there, however, the kind of pattern difference shown, and it could, of course, be argued that if older poor readers were tested, the pattern difference would disappear.

The second main purpose of the present studies was to demonstrate clearly that poor readers perform less well than good readers on even the simplest perceptual discriminations. Surprisingly, poor readers have often been shown to perform equally as well as good readers on such simple tasks (e.g., Black, 1973; Leslie and Calfee, 1971). The results of each of the six studies reported here show significant differences in good and poor readers in grades one through three. The important point to note is that in nearly all the studies, the error rates do not discriminate between good and poor readers. The differences appear only in the reaction times. Apparently, then, reaction times are often a preferable measure to error rates, since they continue to reflect differences in good and poor readers, past the time that they are indexed by error rates.

The importance of speed in performing simple perceptual discriminations should itself be emphasized. A number of researchers (e.g., LaBerge, 1973; Posner and Snyder, 1974), in information-processing are currently examining the role of automaticity in processing. They generally define automaticity as the ability to perform a perceptual discrimination with little or no conscious attention to it. A main index of automaticity is speed. Clearly, automaticity in processing many and various kinds of information is necessary in efficient reading. The studies reported here all seem to indicate that good readers are making much greater progress toward maximal speed on simple discriminations than are poor readers, even on tasks so simple as discriminating line orientation, and in children as old as third graders.

The present reaction time results then, can be argued to support the position that remedial reading classes should spend considerable time on simple perceptual discriminations. But not just accuracy should be stressed (Samuels, 1973). Instead, the goal on these tasks should be toward "overlearning" on the part of poor readers. They should be able to make discriminations accurately but also at a speed equivalent to that shown by good readers. In fact, it does not seem unreasonable to suggest moving toward measurement of reaction times on practice tasks in remedial classes. Such a procedure could be easily and cheaply accomplished. In light of the results reported here, the introduction of such a procedure appears highly warranted.

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Experiment 1

Discriminative Processing of Line Orientation by Good and Poor Readers

Gibson (1965) has emphasized the importance of analyzing distinctive features as a key to good reading. LaBerge (1973) and Samuels (1973) have suggested that efficient reading requires not only the ability to use distinctive features, but further, an ability to analyze distinctive features automatically, automaticity being defined as that process which does not require conscious attention during the time it is being carried out.

In acquisition of skills in analyzing distinctive features, "efficiency" in processing should show at least three major theoretical characteristics. First, analysis must take a very small amount of time. Second, a discrimination should use the smallest number of features logically necessary to characterize the difference. And third, a consistent rather than variable strategy should be used.

Numerous recent studies suggest that children who have reading difficulties but who have no apparent sensory or motor dysfunctions may have problems in basic perceptual processing functions. For example, Edelstein (1971) showed that better readers exhibit more accurate perception of time than poor readers, and suggested that time processing is important in such aspects of reading as perceived sequential arrangements of words and regulating fixation pauses during reading. Reilly (1971) demonstrated in children Grades 1 through 4 that auditory-visual integration is significantly correlated with reading level. Noland and Schuldt (1971), showed that retarded readers exhibited less accurate vigilance behavior than did normal readers. Spring (1971) demonstrated differences in the speed of "central processing" of letters by good and poor readers. What these and other similar data suggest is that many children with reading difficulties may actually be using perceptual processing modes that are less efficient in terms of both speed and accuracy, than modes used by normal readers. Is it possible to demonstrate that poor readers show deficits in perceptual discriminations requiring seemingly the simplest kinds of analysis of distinctive features?

To test this possibility, the present study focuses on a set of distinctive features that has proved itself to be of theoretical importance in at least three disparate areas of psychological research. That set of distinctive features includes those involved in orientation, in its simplest form, the slant of lines. Perception of slant has been of importance in physiological and comparative psychology, in perceptual development, and in cognitive development.

In the tradition of Hubel and Wiesel (1959) and Lettvin, Maturana, McCulloch and Pitts (1959) it has become clear that there exist neural cells differentially sensitive to orientation. In the cortex of kittens (Pettigrew, Nikara and Bishop, 1968) there is evidence that cells responsive to vertical and horizontal orientations are, in fact, more numerous than cells responsive to other orientations. There is behavioral evidence in several subhuman species that certain orientations are easier to discriminate than others. For example, Sutherland (1957) demonstrated that octopi can handle vertical-horizontal discriminations, but not diagonal ones. In humans, Goldstein (1967, 1968) showed that in stabilized images, diagonal lines are more likely to disappear than are horizontal or vertical lines. Wade (1972) showed that although there were no differences in fading in diagonals, verticals, and horizontals monocularly, there was more fading binocularly of diagonals. Essentially, then, there is a suggestion from the physiological and comparative literature of organismic advantage in dealing with vertical and horizontal orientations, and relative disadvantage for slanted orientations.

In developmental perception studies there are similar findings. Rudel and Teuber (1963) showed very little difficulty with discriminations between horizontal and vertical lines in children 3 to 8 years old. But discriminating oppositely oriented diagonal lines, however, was extremely difficult for 3-, 4-, and 5-year olds, becoming easier for 6-, 7-, and 8-year olds. Olson (1970) in an extensive study of ability to deal with diagonality showed that even when children aged 4 and 5 could discriminate diagonal lines, they generally could not reproduce a diagonal pattern of checkers on a checkerboard. Strayer and Ames (1972) demonstrated that although children had especial difficulty matching diagonally oriented shapes, with practice which encouraged attention to orientation, marked improvement was shown in drawing geometric figures containing diagonals, i.e., a rhombus, and diamond. Interestingly enough, McGurk (1972) was able to show that infants as young as six months can discriminate orientation of lines. He suggests that it may be an adaptive strategy for object and shape constancy, for the infant to attend more to identity between different orientations of forms and leave orientation differences themselves relatively unattended.

The problem of slant perception stretches also into the study of developmental cognition. Actually, as Olson (1970) and others point out, perceptual and cognitive processes are probably part of a continuing analytic process, and the distinction is maintained largely for pragmatic reasons. Mackay, Brazendale, and Wilson (1972), in examining conservation tasks, suggest and then empirically demonstrate that abilities to draw horizontals or verticals appropriately largely depend on the "difficulty" of the situation in which conservation must be carried out. Beilin, Kagan, and Rabinowitz (1966) had previously suggested the same kind of notion, but had placed more emphasis on conceptual abilities than on perceptual ones.

Clearly, then, orientation is an interesting and problematical kind of distinctive feature to examine. If it is assumed that poor readers are poor, at least partially because they lack efficiency in analyzing distinctive features, will it be the case that even with an elementary feature like orientation of line, they will show either slower processing or evidence of a mode of processing different from that of good readers? Probably by early grade school, there will no longer be accuracy differences in discrimination of orientation, but there may exist latency differences and, for that reason, reaction times were examined in the present study.

Specifically, three orientation tasks were examined. Task 1 required a button-press response to a line tilted 30 degrees to the right (30R), and no response to a line tilted 45 degrees to the right (45R) (the catch stimulus). Task 2, shown by Rudel and Teuber (1963) to be the most difficult one of those which combines horizontals, verticals, and diagonals, required a button-press to 45R , and a vertical line was the catch stimulus. In Task 3, the response was to be made to a line tilted 45 degrees to the left (45L) and a line tilted 45R was the catch stimulus.

Theoretical Predictions

The theory under which predictions are made combines Gibson's (1965) notion of perceptual differentiation into distinctive features with the assumption that processing strategies go in a parsimonious direction toward use of the smallest number of distinctive features necessary to make a correct choice. In Task 2 of the present experiment, 30R vs. vertical, one feature ("slanted") is sufficient. In Task 3, "slanted to the left" (the top of the line) vs. "slanted to the right" is a sufficient feature. Task 1 is clearly more difficult, at least in terms of a semantic description which, as pointed out by Olson (1970) may well reflect perceptual distinctions. The go stimulus is at a "less acute slant." In other words, probably at least two features, "slant" and "less acute" must be distinguished. Predictions are then, that Task 1 will show the slowest latency, Task 2 and 3 being faster. If it is the case that verticals are easier for the human perceptual system to handle than are diagonals, then the vertical catch stimulus in Task 2 should make it an easier discrimination than that in Task 3. Certainly good readers and adults should show the predicted pattern. Poor and "medium" readers are expected to show variation in patterns, a finding which would indicate they have not established optimal strategies for dealing with even such elementary distinctive features as orientation of line.

Subjects

Three groups of children were selected from each of Grades 1 through 3. In each grade, five children were randomly sampled from groups previously designated as "readers with severe difficulties" (poor), "readers with non-severe difficulties" (medium), and "advanced readers" (good). The designations were made for the school reading program on the basis of teachers' ratings. In addition, five college students with no known reading deficit were run on Tasks 1-3.

Materials and Apparatus

The stimulus lines for the three tasks were presented by readout tubes with 2" x 2" screens. Preceding the stimulus line by 500 msec was a circle flashed on the screen. The child responded to a single button 5 inches to the right of the readout screen and at a tilt 20 degrees from the vertical. Onset of the line stimulus in the screen initiated onset of a Standard Electric timer. The button press from the child produced a stimulus offset and stopping of the timer. Order of go and catch stimuli was controlled by hand by E who sat beside the child. Response times were recorded manually from the timer and the timer was reset before each trial.

Experimental Design

Each S was given all three tasks, with the order of task presentation counterbalanced across subjects. Each of the younger S's received 25 trials of each task, 17 "go" trials and 8 "catch" trials. College S's were given on each of the three tasks 15 "go" trials, and 10 "catch" trials.

Procedure

Each S was run individually. Each S sat 2 feet in front of the screen and was instructed to keep his index finger on the response key at all times. All three tasks were run at one sitting. Before the tasks were begun S received 20 trials of practice on a horizontal (go) vs. vertical (catch) discrimination. Also, before each task, E showed S the two different lines that would be used, explained which one he should respond to, and ran five additional practice trials on that task to ensure that S understood the task. No Ss were eliminated for lack of ability to perform the task. Child Ss were run in a quiet room in the elementary school. College Ss were run in a lab room in the University psychology department. All Ss were instructed to respond as fast and as accurately as possible.

Results

The results of the analysis of variance for the children's data is shown in Table 1. There are significant main effects for grade and task. The results of an analysis of variance on the college students' data are shown in Table 2. As can be seen, task again produces a significant effect.

Table 3 allows comparison of mean reaction times for each reading level in each grade, pooled over the three tasks. There is little difference in the reaction times in the three groups for Grades 1 and 2, but in Grade 3, the good readers are considerably faster than the medium or poor readers. Adults were faster than all children. Grade 3 good readers came closest to adult mean latency.

Figure 1 allows comparison of the pattern of pooled latencies across the three tasks in each grade and reading level, as well as the pattern of latencies across the three tasks for the adult Ss.

As predicted, good readers and college students were slower than on Task 1 and, except for Grade 2, were slowest on Task 3. Although this same pattern held for poor readers, Grade 2, the latency patterns across the three tasks were somewhat different for the remaining groups. Also, instead of showing decreased latencies with each increase in grade, as was expected, medium and poor readers showed slowed latencies in Grade 3.

The probabilities of an error are given in Table 4. Medium readers appeared to make slightly more errors than good or poor readers. College students made many fewer errors than any of the children.

Discussion

Counter to predictions, poor and medium readers are not slower in responding except in Grade 3. In Grade 3, in fact, medium and poor readers showed alower reaction times than their counterparts in Grade 2. This is surprising, especially in view of the seeming simplicity of all three line-discrimination tasks.

In terms of relative difficulty of the three tasks, only the good readers in Grades 1 and 3, and the poor readers in Grade 2 show the predicted pattern. The reason or reasons for the variety of other patterns of latencies across the three tasks is not clear. Looking at response patterns from individual

Ss only muddies the picture. Task 1 does, for nearly all children and college students appear the most difficult task. The relative difficulty, however, of Tasks 2 and 3 is not clear and certainly varies across reading level and grade.

The present study does allow several interesting generalizations to be made. First, as suggested by LaBerge (1973) and Samuels (1973), even after the child has learned to use simple distinctive features, he continues to move toward faster, and presumably more efficient processing of those features. By college age, there is considerably more speed on these simple tasks than has been attained by good readers in Grade 3. Whether the same strategy is being used by the children and college students and the components getting faster, or whether the strategy actually changes, is unclear from the present data.

Second, there is a clear drop in speed on these very simple orientation discriminations for Grade 3 medium and poor readers. Although one would expect these children to make slower progress toward "automaticity" or at least great efficiency with distinctive features, it is surprising to see that they seem actually to lose ground.

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TABLE 1

Summary of Analysis of Variance for the
Grade x Reading Level x Task Interaction (Grade School Children)

Source	df	MS	F
Between	45		
Levels	2	.1327	1.90
Grade	2	.3656	5.24*
L x G	4	.0912	1.31
error (a)	37	.0697	
Within	92		
Tasks	2	.1088	25.30**
L x T	4	.0022	.52
G x T	4	.0037	.88
L x G x T	8	.0071	1.65
error (b)	74	.0043	

* significant at .01 level

** significant at .001

TABLE 2

Summary of Analysis of Variance for the College Students

Source	df	MS	F
Between groups	2	26306.0	7.58*
Within groups	12	3468.3	

* significant at .01 level

TABLE 3

Mean Latencies (msec.) for Children and College Students, Pooled Across Tasks

Grade	Good	Medium	Poor
1	860	875	861
2	695	737	713
3	557	781	809
Adults	443	-	-

TABLE 4

Mean Probability of an Error for Children and College Students

Reading Level

Grade	Good Readers				Medium Readers				Poor Readers			
	Tasks				Tasks				Tasks			
	1	2	3	Combined	1	2	3	Combined	1	2	3	Combined
1	.13	.05	.08	.09	.13	.10	.18	.14	.05	.05	.13	.08
2	.18	.13	.18	.16	.23	.23	.23	.23	.13	.10	.25	.16
3	.18	.23	.08	.16	.05	.18	.18	.14	.18	.23	.13	.18

	Task 1	2	3	Combined
College Students	.02	.02	.02	.02

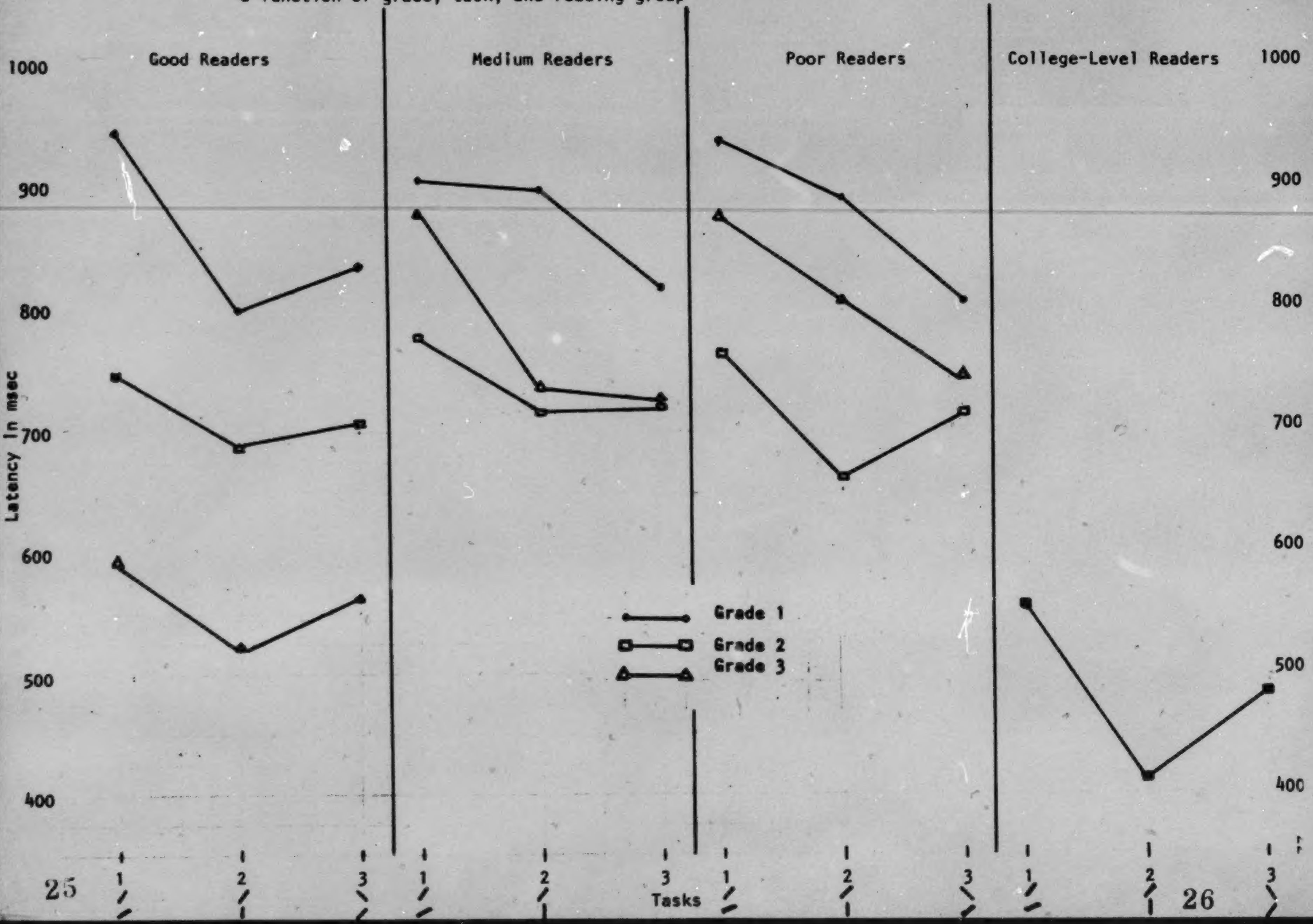

Figure 1: Mean latencies for college-level readers, and for grade school level readers as a function of grade, task, and reading group

Experiment 2

Reaction Times of Good and Poor Readers to a Word and its Component Letters

The study reported here is part of a series aimed at determining whether poor readers use information-processing strategies demonstrably different from those of good readers. E.J. Gibson suggests (1965) that in learning to read, two of the most important initial steps are: (1) learning to discriminate the distinctive features of letters, and (2) learning to discriminate the distinctive features of words. Both of these abilities clearly involve basic kinds of perceptual processing, and it is toward these basic processing activities that the present research is aimed. Whether slow readers have trouble processing distinctive features of letters seems to depend on what kind of task must be performed on the letters. Katz and Wicklund (1971) showed, for example, that in scanning for letters, slow and fast readers showed no latency differences. Spring (1971), however, showed that in matching capital letters, slow readers are slower than fast readers.

A question related to that of reaction times to single letters concerns what happens to the perceptual processing mechanisms of slow readers when letters are put together into words. Without taking a position on whether letters are identified by matching templates or by matching distinctive features, there are three logically possible temporal alternatives for carrying out the processing of the word. It must be noted, however, that there exists a limitation to these three possibilities only when a situation is arranged so that it is necessary to check each letter before deciding what the word is. Alternative 1 is where the reader checks each letter in turn (Pure Serial). Alternative 2 allows discrimination of the letters to go on simultaneously, but suggests that the beginning processing of each letter must occur serially (Sequential Start Parallel). Alternative 3 is where the reader checks all letters simultaneously (Pure Parallel).

(It should also be noted that the sequential start parallel model makes empirical predictions about reaction times that are not differentiable from a model that suggests pure parallel processing with the processing time for each letter slightly expanded.)

If a three-letter word is processed serially, processing reaction time should equal the summation of reaction times to each individual letter, minus motor time, plus one motor time component. A reasonable estimate for the motor time in a simple reaction time is 200 msec. If a word is processed in a pure parallel way, the reaction time required to process it should equal the latency required to do the most difficult letter. The Sequential Start Parallel model predicts that the latency to process the word will be greater than the latency of the slowest letter and less than the serial processing latency.

The goal of the present experiment is threefold. First, it seeks to discriminate which of the above three models of word processing are being used by good and poor readers. Second, it seeks to determine whether, in a discrimination task, slow readers will perform more slowly on letter stimuli than good readers. Third, it seeks to determine whether poor readers show more difficulty in discriminating words than do good readers, once relative performance on letter stimuli is controlled. To make these three determinations, a word is used as the "go" stimulus, and six "catch" stimuli randomly distributed into the trials force the child to check every letter position before issuing a response. Then individual letter discriminations are made between the component letters of the go word and the appropriate catch letters. In this way the relationship between latencies to processing single component letters, latencies to process whole words, and the relationships between those latencies can be compared for good and poor readers. If slow readers show a difference between single-letter and whole-word processing that is equal to fast readers, there is indication that their problem with words lies primarily with individual letters. If, however, the difference between single-letter and whole-word processing is greater for slow than for fast readers, there is indication that for the slow reader, a problem lies both in discriminating the distinctive features of letters and in discriminating the distinctive features of the word.

Method

Design

To examine the hypothesis, latencies to the word "fun" (with catch stimulus words "bun," "fan," and "fur") were compared to latencies to the component individual letters ("f" with "b" as the catch stimulus, "u" with "a" as the catch, and "n" with "r" as the catch). The order of presentaiton the four tasks was counterbalanced across subjects.

Each subject received 20 trials on the word task, including 6 catch-trials. Ten trials were given on the three single-letter tasks, each including three catch trials. If a child made more than two errors in the word task or more than one error in the single-letter task, that task was completely repeated at a later time. The order of the trials in the tasks was randomized.

Subjects

Students had been previously rated by their teachers as being poor, medium, or good readers. Five good and five poor readers from each of Grades

1, 2, and 3 were then randomly selected from the pool provided by the teachers' ratings.

Materials and Apparatus

Slides of typed stimulus words and letters were made and projected onto a back-lighted screen in front of the subject. A tachistoscopic shutter in front of the projector controlled stimulus onset and offset. On each trial the slide tray was manually changed. A button-press by the experimenter initiated virtually simultaneous opening of the tachistoscopic shutter and starting of a Standard Electric Millisecond timer.

The subjects sat approximately 30 mm from the screen, the stimuli distending a visual angle of approximately 1.4 degrees. A response button was located immediately in front of the subject. Pressing the response button both closed the shutter and stopped the clock. The clock time was recorded manually by the experimenter, and then reset.

Procedure

Each subject was tested individually in a quiet room in the school. Subjects were instructed to keep their index and middle fingers on the response button at all times. No trial was started until the subject was fixating that part of the screen in which the stimulus would occur. All four tasks were tested at one sitting, unless the error rates required additional testing. Before each task, the subject was shown the word or letter to which he was to respond and those words or letters which were catches. Then on all four tasks the subject was given five practice trials. If the subject still seemed confused, additional practice trials were given. No subjects were eliminated for lack of ability to perform the tasks.

Results

False alarm error rates are shown in Table 1. As can be seen, poor readers made slightly more errors than did good readers. Poor readers also had a larger number of blocks of trials which had to be retested because initial error rates were unacceptably high. The difference in error rates between good and poor readers does not pose a problem to interpretation of the reaction times, since on all tasks, poor readers are slower. The effects of their slightly higher error rates can be taken into account simply by assuming their reaction times to be somewhat higher than they appear, thereby only increasing the difference between their latencies and those of the good readers.

The comparisons of reaction times for the good and the poor readers, Grades 1, 2, and 3, for the four tasks are shown in Figure 1. As shown in the analysis of variance summarized in Table 2, there are significant main effects for reading level, grade, and task. The good readers at all grades are faster on all four tasks.

As can be seen in Table 3, predictions for the word-task reaction times are much closer for the parallel than for the serial model. It is not possible to distinguish between the serial-start and the parallel model, since the former does not make quantified predictions without further elaboration. Two points are, nonetheless, important to make. The first is that the differences between the observed latencies and those predicted by the parallel model decrease across grades for both reading levels. This would have to imply that if sequential-start processing is operating, the start-times must be closer together in the higher grades. A second important aspect of the data is the variation in differences between observed reaction time in the word task and the parallel prediction as a function of reading level. The poor readers are much slower on the word-task as compared to the letter-tasks than the fast readers are. This pattern is reflected not only in the pooled latencies, but is repeated at the individual level in 73 percent of the poor readers and 73 percent of the good readers.

The fact that third grade poor readers average longer reaction times than second grade poor readers is not a trend repeated at the individual level, but results from one third grade subject who produced extraordinarily long latencies on all four tasks. As can be seen in Figure 1, elimination of that subject puts the third grade poor readers at a level approximately equivalent to that of the second grade poor readers.

Discussion

The most striking aspect of the data reported here is the fact that poor readers at all grades perform so much more slowly than good readers -- in spite of the seemingly simple nature of the tasks. It is unconvincing to argue that the performance differences can be attributed to motivational differences. All children were reported to be excited about being taken out of the classroom, and since the tasks took up only a short period of time, all children were able to sustain interest and enthusiasm about "playing the game." When even under high motivational levels and with a very simple task, poor reader performance is so much slower, it is not at all surprising that the lag is so great at the much more complex level of actual fluent reading.

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Table 1

Mean Probability of a False Alarm

Error for Each of the Four Tasks

	Tasks			
Grade	Word (fun)	Letter 1 (f)	Letter 2 (u)	Letter 3 (n)
		Poor readers		
1	.17(2)	.13	.20(2)	.20
2	.13(2)	.13	.20(1)	.27
3	.17	.07	.00	.00(1)
		Good readers		
1	.20	.20	.07	.07
2	.20(1)	.00	.13	.07
3	.17	.00	.13	.20(1)

Note. The numbers in parentheses refer to the number of blocks which were retested because of unacceptably high error rates.

Table 2

Summary of Analysis of Variance

for Grade X Reading Level X Task

Source	df	MS	F
Between	29		
Reading level	1	499746	9.32[1]
Grade	2	331688	6.19[1]
Reading level X Grade	2	51991.3	.97
Error (a)	24	53606.1	
Within	90		
Tasks	3	66186.2	10.4[2]
Level X tasks	3	16926.3	2.66
Grade X tasks	6	15755.9	2.48
Level X grade X tasks	6	21589.9	3.39
Error (b)	72	6365.8	

[1] Significant at $p<.01$

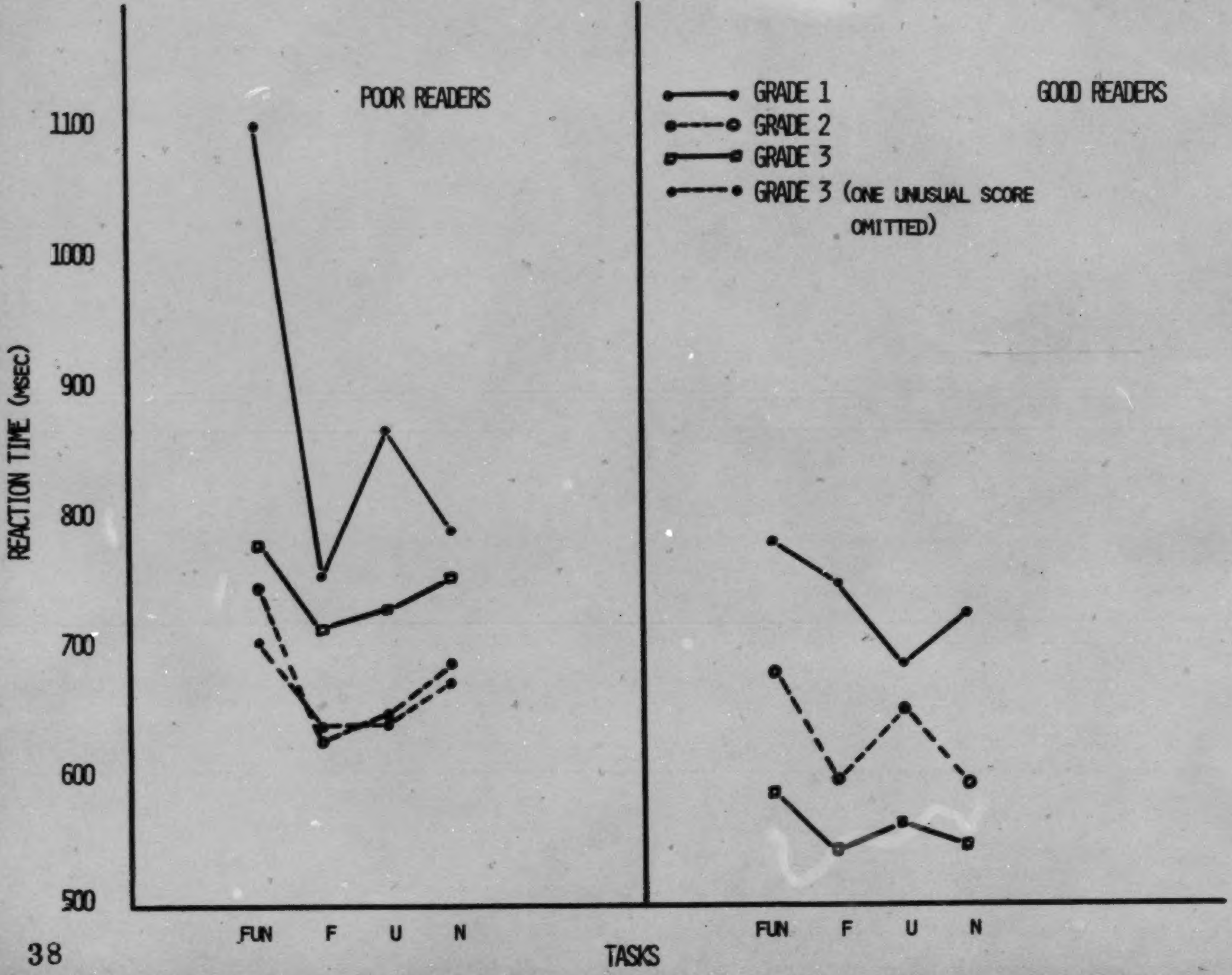
[2] Significant at $p<.001$

Table 3: Predicted and Observed

Reaction Times for the Word-Task

Grade	Predictions		Observed
	Pure Parallel	Pure Serial	
	Good readers		
1	722	1766	783
2	619	1456	683
3	551	1252	586
	Poor readers		
1	808	2024	1105
2	663	1598	746
3	754	1803	783

FIGURE 1: REACTION TIMES OF GOOD AND POOR READERS TO THE WORD AND LETTER TASKS



Experiment 3

Reaction Times of Good and Poor Readers to Single Letters and Letters Embedded in Words or Sentences

The present study is part of a series examining patterns of differences in performances on simple discrimination tasks by good and poor readers. That there are clear differences was shown in tasks requiring differential response to lines at various orientations (Thorson, 1974a), tasks requiring switching after the start of the stimulus from a letter discrimination to a meaning discrimination (Thorson, 1974c), and a task requiring either differential response to simple letters or to words (Thorson, 1974b). In all three kinds of tasks, poor readers start out and remain slower in overall latencies than good readers. In the line-orientation task, although it was expected that the simple nature of the task would produce no differences in latencies across tasks, poor readers varied greatly for the various line pairs they had to distinguish. Good readers varied some, but to a lesser degree. Adults showed no latency differences across the tasks except for the line pair tilted in the same direction, one 45 degrees, the other 30 degrees. Line orientation, basic to so much of the visual discrimination that must go on in reading, seems to be automatic for good readers and adults, and each discrimination goes on in the same period of time. Even third-grade poor readers, however, have not reached such a response level.

In the switching study, first grade poor readers are much slower in matching both letters and words with pictures corresponding to the words. Second and third grade poor readers are only slightly slower on the letter-matching than their good-reader cohorts, but remain much slower in matching words with pictures. Having to switch from preparation for one task to performance of the other led to much greater response decrement for the poor readers compared to good readers, only for first-grade poor readers and only on the letter-matching task. Here, again, then, poor readers do not perform well even on another very simple information-processing task, although the switching between tasks which intuitively seems more difficult did not cause the problems that were expected for the poor readers.

In the study comparing latencies in tasks requiring discrimination of three letter words, and their component letters, good readers showed latencies to the word that were nearly as short as latencies to the single component letters at Grades 1, 2, and 3. Poor readers, only slightly slower on letter-discrimination responses, showed, at least in Grade 1, a large differential between single-letter and word-discrimination latencies. This would seem to indicate that at least initially, poor readers have great difficulty in discriminations when letters are put together into words.

The findings discussed above indicate that poor readers do produce slower discriminatory responses to simple stimuli than do good readers. Is this finding of importance to understanding the reading deficits of poor readers? Samuels' (1973) analysis of the technology of reading suggests that in learning to read, "accuracy (of simple discriminations) is not enough. The student must go beyond accuracy, to the level of automaticity, a level in which an accurate response can be given with little conscious effort." Although Samuels does not completely define automaticity, he does specify that its main index is speed. Other researchers (e.g., LaBerge, 1973; Posner and Snyder, 1973; Posner and Snyder, 1974) suggest that automaticity (or "automatic activation processes") occurs when processing goes on without conscious attention, and when its occurrence does not inhibit any other processing.

The study reported here is designed to analyze more closely whether the slower speed of responding shown by poor readers can be attributed to lack of automaticity. The task used is similar, though not equivalent to that used by Reicher (1969), Wheeler (1970), and Krueger (1970), all of whom presented subjects tachistoscopically with single letters or letters embedded in words or pseudowords and asked them to identify the letters. In Reicher's (1969) study, whose results were typical of all the studies, it was found that the letters were identified correctly on 64 percent of the trials, when presented singly, and on 73 percent of the trials when presented in words.

The finding of single letter identification being aided by its placement in a word is referred to as context facilitation. The implication is that other kinds of simultaneous processing that go on in words facilitate the letter identification processing. In a paradigm otherwise identical to Reicher's, Thompson and Massaro (1973) told subjects before stimulus presentation which of two letters they would have to decide between and thereby eliminated the word-facilitation. They argued convincingly that this result demonstrates that context-facilitation results from the redundancy of information available in words. This then is further confirmation that asking subjects to discriminate letters in words is producing a task wherein automatic processing of at least two sets of information is likely to go on simultaneously, one kind of processing, in fact, actually facilitating the other. Interestingly, the presence of other letters has not been shown, at least for adults, to inhibit discrimination of component letters. The findings that poor readers, especially first-graders, show so much difficulty when letters are put together into words (Thorson, 1974b), may be an indication that poor readers will exhibit context-inhibition rather than facilitation. In fact, given the complexity of initially learning to analyze letters grouped into words, even younger good readers may show the same effect.

To test the hypothesis that context-inhibition or, in other words, lack of automaticity may occur in all younger readers, and continue to appear in even older poor readers, a simple paradigm was designed. Children were shown at the beginning of each block of trials two letters they would be asked to discriminate. One letter (the positive-set stimulus) required a button press; the other (the negative-set stimulus) served as a "catch" stimulus. To make the discrimination as simple as possible, the letter always occurred at the beginning of whatever stimulus string was presented. The letter was presented in three contexts: a) singly; b) in a word; or c) in a sentence.

In choosing the three pairs of letters that were used, the cluster analysis of letters reported by Gibson, Schapiro, and Yonas (1968) was used. They obtained confusion matrices from seven-year-old children for two sets of nine capital letters and then by examining the way the latencies for discriminating pairs of letters clustered, produced hierarchical structures implying sequential use of distinctive features of the letters such as slant, straight lines, curves, or horizontals to distinguish them. The hierarchical analysis is shown in Figure 1. Letters on different branches at the top of the structure are easier (take fewer distinctive feature analyses) to discriminate. Those farther down in the structure are more difficult. An easier discrimination (Task 1: E-B), and a more difficult discrimination (Task 2: Z-N) were selected for use in the present experiment and both placed into three-letter words. A discrimination equa[illegible]ficult to Z-N (Task 3: K-N) was also chosen, but the letters were placed into a four-letter word.

Having sampled in this way the letter-pairs to be discriminated, the following predictions were made. Older good readers should be able to discriminate with equal latencies across the letter, word, and sentence trials, but may show overall slower responses for K-N and Z-N discriminations than for B-E. Poor readers and the youngest good readers are expected to show context inhibition when letter and word conditions are compared. This prediction is based on the assumption that automaticity in processing aspects of the word and aspects of the letter is not occurring. Because the adding of words to make a sentence is done at a point considerably removed from the letter to be discriminated, there probably will not be more inhibition in the sentence than the word condition. Since the children will all know before each trial what letters to discriminate, context facilitation should, as in the Thompson and Massaro study, not occur.

Method

Subjects

Students were rated by their teachers as being poor, medium, or good readers. Five good and five poor readers from Grades 1, 2, and 3 were randomly selected from the pool provided by the teachers' ratings.

Design

The three contexts: a) single letter; b) word; and c) sentence, were tested for each of the three letter-pair tasks. The conditions for each single letter-pair were presented together, although the order of the three conditions was counterbalanced. Order of presentation of the three letter-pair tasks was counterbalanced across subjects. Each child, then, performed nine blocks of trials (e.g., Task 1, contexts a, b, and c). For each block, the child received five practice trials, and then 13 recorded trials. Ten recorded trials in each block contained positive-set stimuli and required a response. Three trials contained the negative-set stimuli. For the K-N task, K was the positive stimulus, for the Z-N task, Z was the positive stimulus, and for the B-E task, B was the positive stimulus.

Stimuli and Apparatus

Each letter, word, or sentence was presented on a slide which had been taken of a typed stimulus. The three tasks, each consisting of a positive-response and a negative-response letter, word, and sentence, are shown in Table 1. The slides were projected onto a back-lighted screen directly in front of the subject. A tachistoscopic shutter in front of the lens of the projector opened simultaneously with onset of a Standard Electric timer. A response button was situated immediately in front of the subject, below the screen. A button-press turned the timer off on trials where the subject responded. On the other trials the experimenter pressed an auxilliary button to turn off the timer. After each trial the shutter was closed, the latency was recorded, and the timer was manually reset. The subject sat approximately 30 cm from the screen, the stimuli distending approximately 1.4 degrees of visual angle.

Procedure

Each subject was tested individually in a quiet room in the school. All three tasks were run at one sitting. Before each condition of the three letter-pair tasks, the subject was shown sample slides and was given five practice trials to assure understanding of the task.

The subject was instructed and frequently reminded to respond as quickly as possible but not to make errors. Before initiation of each trial, the experimenter checked to see that the child's eyes were directed at the appropriate position on the screen, and that his index and middle fingers rested on the response key. The experimenter praised fast and accurate responses, and reprimanded when a slow or an incorrect response was made.

Any block in which more than two errors were made was immediately terminated, and the subject was retested on that block at a later time. At the end of a session, the subject was thanked for performing well on the test. The testing procedure generally required about 25 minutes for each subject.

Results

False alarm probabilities for the nine task-context blocks are shown in Table 2. No subjects required blocks to be rerun because of unacceptable error rates. As can be seen, Grade 3 poor readers made slightly more errors than those in Grades 1 and 2. Grade 2 good readers also show slightly higher mean latencies than those in Grades 1 and 3. Error rates across the nine task-blocks are fairly equal. It should be noted that in any study examining reaction times, the tradeoff relationship operating between speed and accuracy is a problem if different groups make the tradeoff differently. A reasonable approach is to assume that the less accurate group should have a constant added to their reaction times in order to be made comparable to the more accurate group. Since the poor readers are slower on every task than the good readers, the assumption of an added constant is not problematical.

Reaction times for each of the nine task-context blocks are shown for good readers in Figure 2 and poor readers' reaction times are shown in Figure 3. Tables 3, 4, and 5 show analysis of variance results for each of the three letter-pair tasks individually. As can be seen, the reading level effect is significant for all three tasks. There are significant grade effects in Tasks 1 and 2, but not in Task 3, and there are also significant context effects in Tasks 1 and 2, but not in Task 3. No interactions are statistically significant.

Results for reaction times pooled across the three tasks are shown in Figure 4. As can be seen, there is virtually no context effect for good readers in any grade except that they are slightly slower on the word and sentence contexts than in the letter context. Poor readers, at least in the first grade show increasing slowness across the three contexts. Grade 1 poor readers show mean reaction times approximately 100 msec slower than Grade 1 good readers, but by Grades 2 and 3, the difference in good and poor readers has been lowered to only about 50 msec.

Discussion

A first conclusion to be derived from the results is that neither good nor poor readers are aided in discrimination of letter-pairs when they are presented in context with other letters. These outcomes are not directly comparable to those of Reicher's (1969), Wheeler's (1970), or Krueger's (1970) since the experimental paradigm was dissimilar. In fact, the paradigm is closer to that of Thompson and Massaro (1973) in that the alternatives are explained in detail to the subjects before each block of trials. That procedure presumably lessened the probability that redundancy of information resulting from previous knowledge of sequences of letters in words would be available for use. To test the relation between tachistoscopic and non-tachistoscopic presentations, the present paradigm, of course, should be replicated using an adult sample.

A further comparison to be noted is that between the results reported here and those of Smith (1969) and Lott and Smith (1970). These studies, the first testing adults, the second testing children in Grades 1 through 4, examined facilitation resulting from knowledge of sequential dependencies among letters in words. Lott and Smith (1970) increased contrast from a point when displayed words or letters could not be read, up to recognition level. They found that first through fourth graders were facilitated (required a lower contrast ratio) to recognize letters embedded in words than to recognize letters alone. The amount of facilitation increased through Grade 4, and children in Grade 4 showed the same amount of facilitation as adults had previously (Smith, 1969). The authors concluded in the developmental study that children seem to have reached "asymptotic performance on simple words. . .before fifth grade."

It is clear that since the present study eliminates sequential redundancy as a cue, results matching those of Lott and Smith are not expected. Nevertheless, the results of the present study, together with similar findings relating single-letter latencies and word latencies (Thorson, 1974b) would indicate that Lott and Smith's conclusion is probably not warranted for poor readers. All performances on simple words are not at asymptotic for poor readers, at least in the sense that they match adults' or even good readers' asymptotes. Not only do few of the groups tested here show facilitation from the contexts, they frequently show "context inhibition." Both good and poor readers in Grade 1 are slowed in making letter-pair discriminations when they are placed in sentence or phrase context, regardless of the difficulty of the letter-pair discrimination itself.

Since sequential redundancy effects have presumably been eliminated in the present design, context-inhibition similar to that phenomenon reported by Thompson and Massaro (1973) is not unexpected. Poor readers in Grades 2 and 3 also exhibit context-inhibition, although the effect is less marked. Good readers in Grades 2 and 3, on the other hand, show approximately equal reaction times across the three contexts.

A final point regarding the present results concerns the general problem of the effects of irrelevant stimulation on children's processing of letters. Many developmental studies (e.g., Osler and Kofsky, 1965; Lubker, 1969) document the fact that younger children tend to respond to irrelevant cues. For example, Lubker (1967) presented eight- and ten-year-old children with a two-choice discrimination in which up to three dimensions were varied: form, brightness, and size. Only one dimension was relevant to the discrimination. Learning was significantly slower with one or two irrelevant dimensions present. The results reported here substantiate the detrimental effect on discriminating letters that an "irrelevant context" (that is, other letters) has. This effect is marked in all younger readers, but is especially strong in the first-grade poor readers. Further evidence is provided, then, that a seemingly simple problem, namely discriminating letters in the contexts of words (or phrases) is not a simple problem to the poor reader.

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Table 1

Letter, Word, and Phrase Stimuli Presented
in the Nine Letter-Pair Blocks

Letter		Word		Phrase	
Positive	Negative	Positive	Negative	Positive	Negative
		Task 1			
E	B	Eat	Bat	Eat the top	Bat the top
		Task 2			
Z	N	Zip	Nip	Zip the cap	Nip the cap
		Task 3			
K	N	Kick	Nick	Kick the cap	Nick the cap

Table 2

Mean Probability of a False Alarm[1]

for Each Context of the Three Letter-Pair Tasks

	Task-Context Blocks									
Grade	1A	1B	1C	2A	2B	2C	3A	3B	3C	Mean for all blocks
					Poor readers					
1	.00	.13	.20	.20	.20	.13	.13	.13	.07	.13
2	.07	.20	.20	.13	.00	.13	.13	.13	.20	.13
3	.33	.47	.07	.20	.20	.27	.40	.33	.20	.27
Mean for grades 1-3	.13	.27	.16	.18	.13	.18	.22	.20	.16	
					Good readers					
1	.07	.27	.07	.20	.13	.00	.07	.20	.07	.12
2	.20	.27	.20	.27	.20	.20	.13	.13	.27	.22
3	.07	.13	.13	.00	.13	.27	.27	.13	.13	.14
Mean for grades 1-3	.11	.22	.13	.16	.15	.16	.16	.15	.16	

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[1] A false alarm error is defined as a button-press on trials when a negative-set stimulus occurs.

Table 3

Summary of Analysis of Variance for

Reading Level X Grade X Task

(Task 1, E-B Discrimination)

Source	df	MS	F
Between	29		
Reading level	1	462393.0	6.23[1]
Grade	2	445574.0	6.00[1]
Reading level X Grade	2	18073.4	.24
Error (a)	24	74267.8	
Within	60		
Tasks	2	137473.0	22.69[2]
Level X Tasks	2	3780.8	.62
Grade X Tasks	4	8030.5	1.33
Level X Grade X Tasks	4	10771.8	1.78
Error (b)	48	6059.9	

[1] Significant at $p<.025$

[2] Significant at $p<.001$

Table 4

Summary of Analysis of Variance for
Reading Level X Grade X Task
(Task 2, Z-N Discrimination)

Source	df	MS	F
Between	29		
Reading level	1	730441.0	8.97[1]
Grade	2	861239.0	.58
Reading level X Grade	2	3028.0	.04
Error (a)	24	81395.0	
Within	60		
Tasks	2	49006.1	1.73
Level X Tasks	2	26119.5	.92
Grade X Tasks	4	87725.9	1.55
Level X Grade X Tasks	4	17785.1	.31
Error (b)	48	677917.0	

[1] Significant at $p<.01$

Table 5

Summary of Analysis of Variance for
Reading Level X Grade X Task
(Task 3, K-N Discrimination)

Source	df	MS	F
Between	29		
Reading level	1	732965.0	9.36[1]
Grade	2	751160.0	9.59[2]
Reading level X Grade	2	60501.9	.77
Error (a)	24	78305.1	
Within	60		
Tasks	2	117241.0	15.32[3]
Level X Tasks	2	4361.5	.57
Grade X Tasks	4	14488.3	1.89
Level X Grade X Tasks	4	3520.6	.46
Error (b)	48	7654.0	

[1] Significant at $p<.01$

[2] Significant at $p<.005$

[3] Significant at $p<.001$

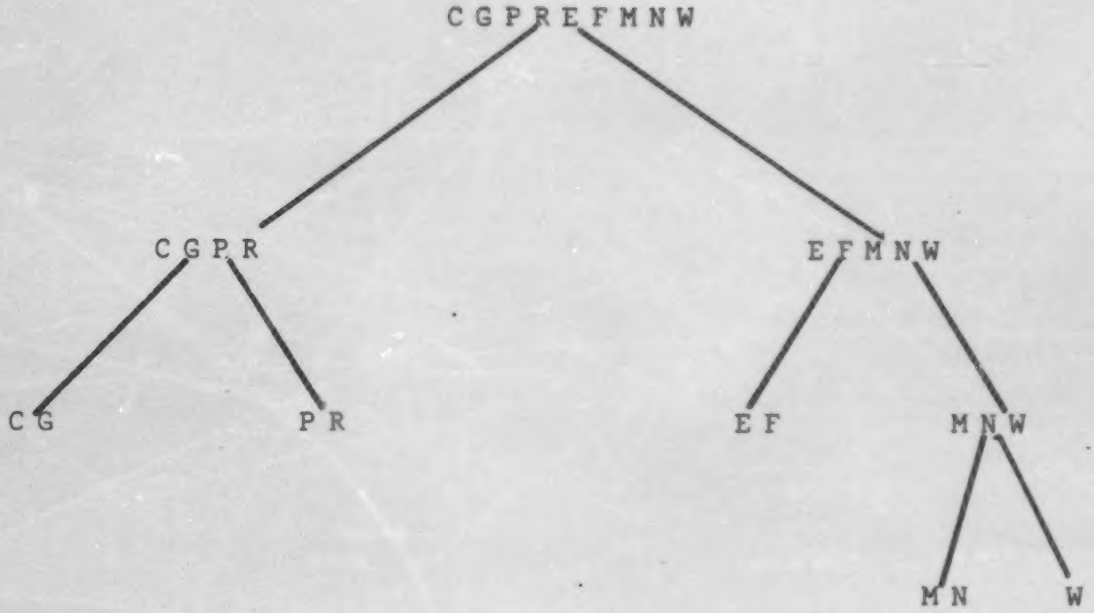

C G P R E F M N W
C G P R
E F M N W
C G
P R
E F
M N W
M N
W

Figure 1: Results of a hierarchical cluster analysis of reaction times for discriminating pairs of letters by seven-year-old children (from Gibson, Schapiro, and Yonas, 1968).

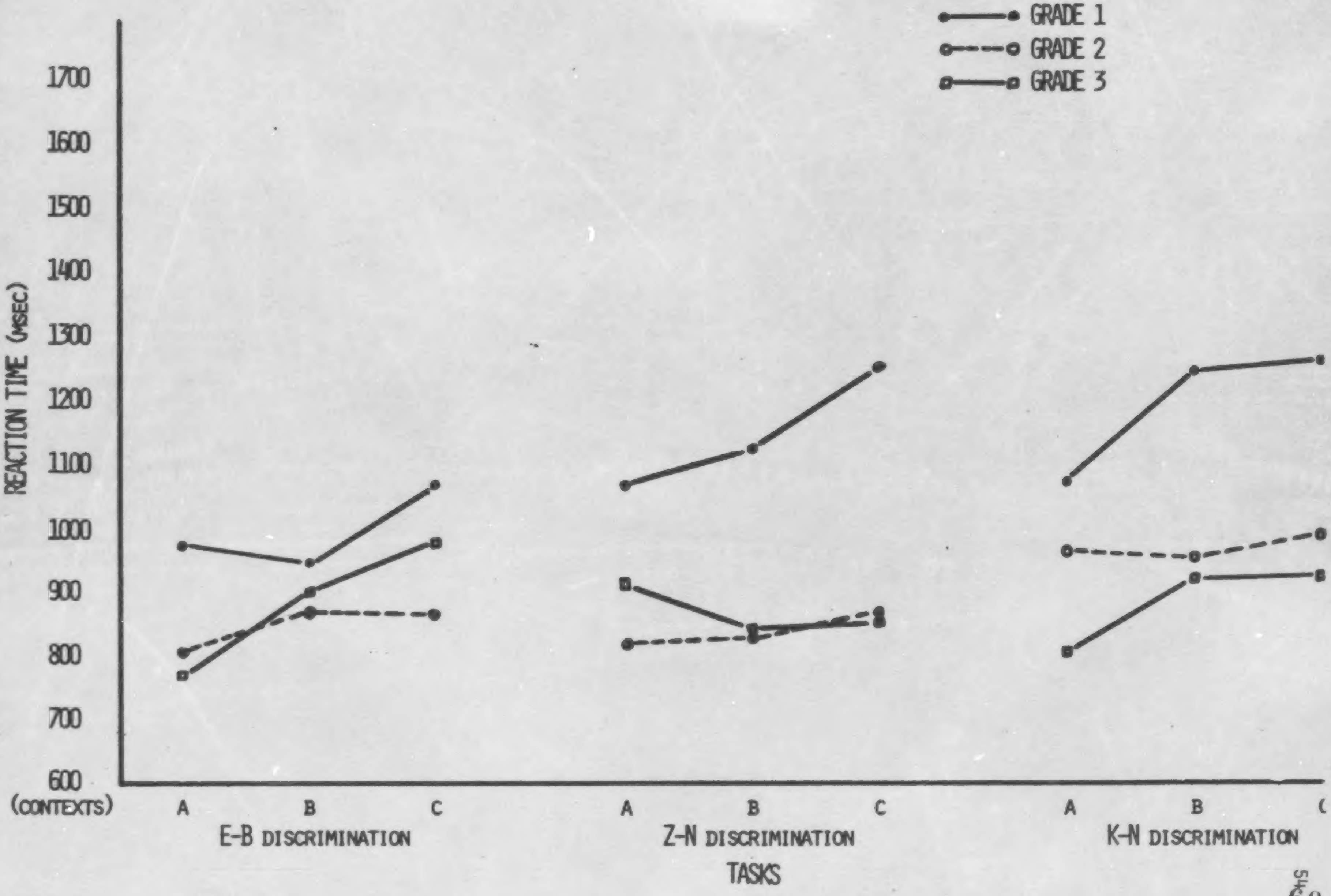


FIGURE 2: REACTION TIMES OF POOR READERS ON LETTER-DISCRIMINATION TASKS

FIGURE 3: REACTION TIMES OF GOOD READERS ON LETTER-DISCRIMINATION TASKS

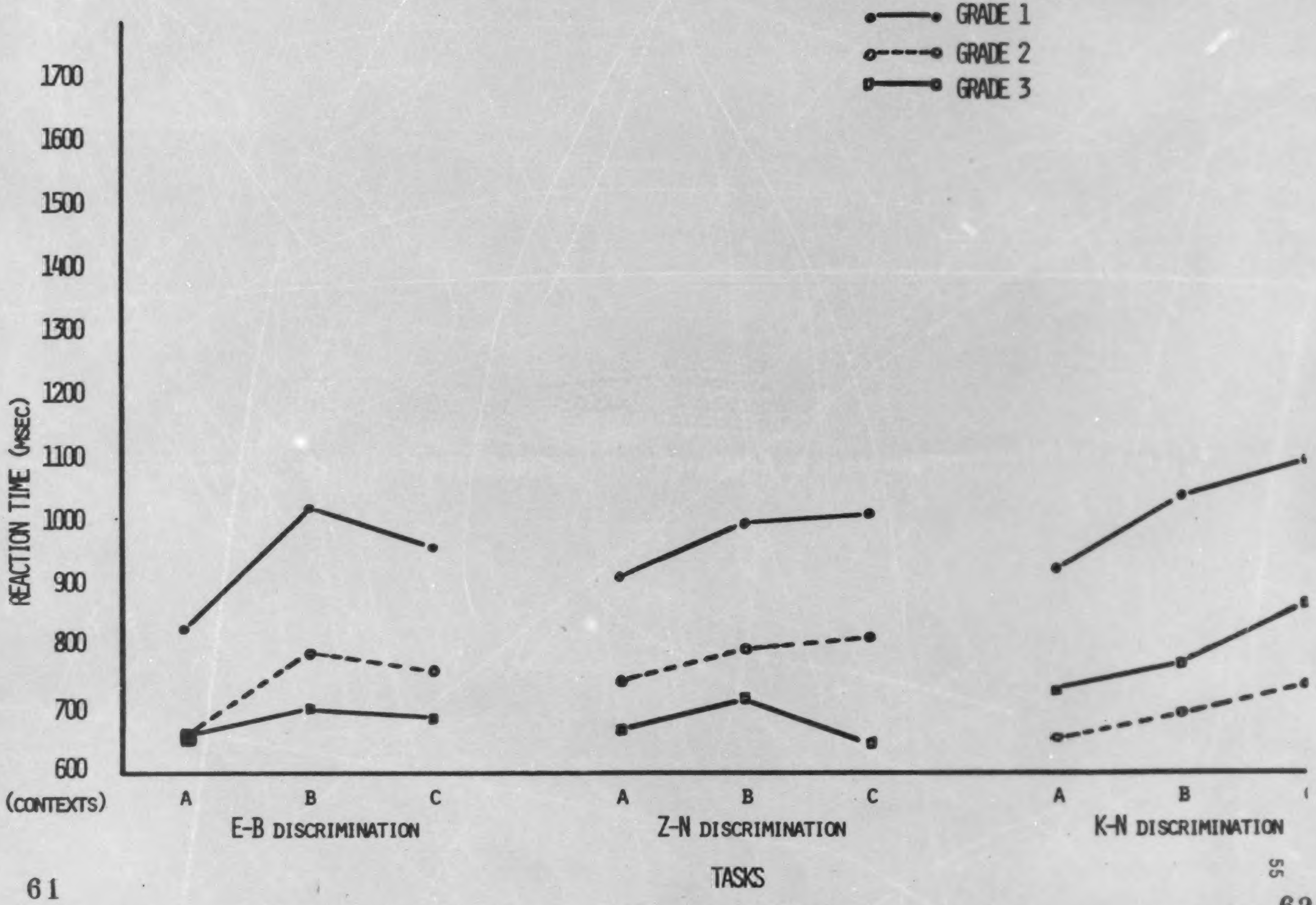
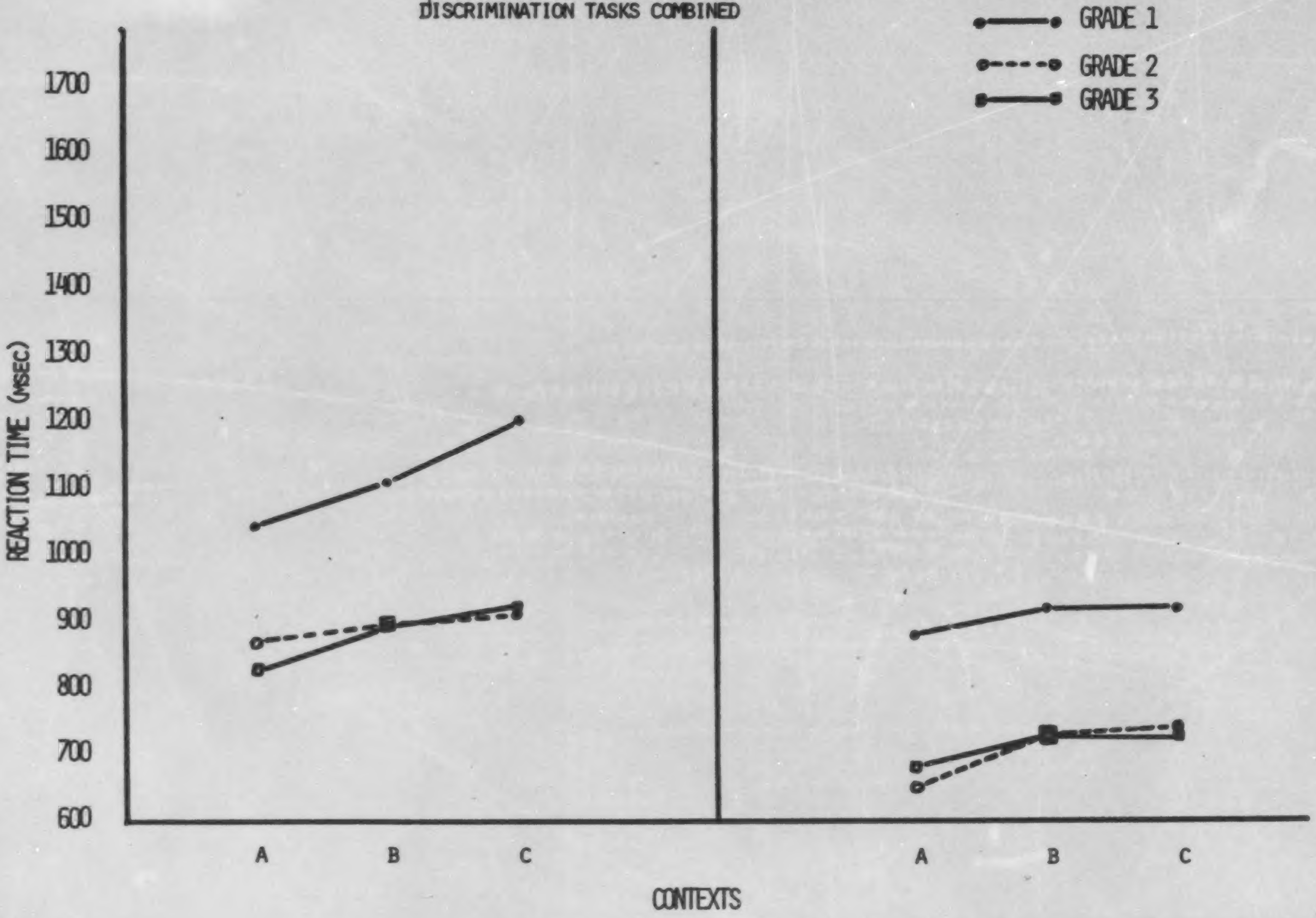


FIGURE 4: REACTION TIMES OF GOOD AND POOR READERS FOR THE THREE LETTER-DISCRIMINATION TASKS COMBINED



Experiment 4

Matching Auditorally and Visually Presented Letters: Latencies of Good and Poor Readers

Auditory-visual integration intuitively seems to be an important skill in the acquisition of efficient reading performance. Much research has in fact been aimed toward discovery of correlations between reading skill and various measures of auditory-visual integration skills. This research largely has taken one of two kinds of approach. One approach has involved requiring children to match patterns of stimulation across two modalities. An early example of this task was reported by Birch and Belmont (1964). They reported that reading ability was correlated with ability to match a visual pattern of dots to a rhythmic pattern of taps. Sterritt and Rudnick (1966) criticized the Birch and Belmont study for indexing ability to match temporal relations to spatial ones, rather than ability to perform auditory-visual integration. Kahn and Birch (1968) criticized the Birch and Belmont study in view of the possibility that different children used different strategies to perform the matching task. Some children apparently counted the groups of taps, while others coded verbally aspects of the patterns.

A further criticism of the Birch and Belmont technique concerned its reliance on short-term memory, which is clearly necessary to the matching task, but may be operant at different levels in good and poor readers. Vande Voort, Senf, and Benton (1972) tested the memory hypothesis by varying the time interval between presentation of the two stimulus patterns. Unfortunately, the interval manipulation had no significant effect, making direct interpretation of the role of short-term memory impossible. The study included, however, a simultaneous presentation condition, in which poor readers maintained their reduced performance level. Taken together, the two manipulations do seem to cast doubt on the memory hypothesis.

A fourth criticism of the Birch and Belmont paradigm concerns the possibility that apparent difficulty with cross-modal matching actually results from inability to discriminate the stimuli in one or both of the other component modalities (Bryant, 1968; Kuhlman and Wolking, 1972). Kuhlman and Wolking (1972), presenting all tasks with temporal differences among stimuli, found no difference in within- and cross-modality problems. Vande Voort, Senf, and Benton (1972) found the same general result.

In general, then, the results of cross-modality matching tasks do not clearly point in one direction with regard to reading ability. That is, the poorer performances of younger children and poor readers may be due to a multiplicity of factors. It can be said, however, that some aspect of the task does predict to less mature developmental level and to poorer reading abilities, and researchers do continue to use the general Birch and Belmont paradigm. For example, Gregory and Gregory (1973) report a modified paradigm which examines performance on a Morse-code stimuli differentiating sections of the visual and the auditory patterns temporally.

A second general approach to auditory-visual integration relies to an even greater extent on memory abilities. In an early study, stemming from the Broadbent (1958) approach to studying cross-modality attention, Margrain (1967) presented simultaneously two different lists of letters, one auditorally- and one visually-presented,asking subjects to shadow one list or the other. She then required reporting of one or the other of the two lists. Dornbush (1968a, 1968b, 1969) performed further similar studies, agreeing with Margrain that performance on the auditorally presented lists was better. Horowitz (1969) used a similar procedure to examine developmental trends, but presented the same material to both modalities and did not require shadowing. He found that both kindergarten and third-grade children performed better on simultaneous auditory-visual presentations than on either modality alone. Similarly, Siegel and Allik (1973) either presented pictures (visual) or names (auditory) of objects and then varied the recall cue (either visual or auditory) presented to the child. These researchers found that for kindergarten, second-, fifth-, and college-aged children, recall of visual stimuli was significantly superior than recall of auditory stimuli and that modality of the recall cue had no significant effect.

Taken together, these memory studies show clearly that the task demands themselves determine how well both children and adults use auditory and visual information. When stress is placed on the system as in the Margrain and Dornbush studies, there appears to be an auditory preference. When the same information is available from both modalities, two modalities seem better than one (Horowitz, 1969). In performance in just a single modality, vision seems superior (Siegel and Allik, 1973) but this effect could just as easily be attributable to a better image than verbal memory for simple objects.

Overall, then, available data do not allow clear inferences about the relation of auditory-visual performances and integration to reading ability. Both approaches described briefly above, in fact, would seem to place too much reliance on memory abilities to be directly relevant to the auditory-visual integration process that must go on in reading. Posner, Lewis, and Conrad (1972) point out, for example, that "consciousness of the letter [A] is suffused with past experience: its association to other visual forms (e.g., "a"), the phoneme /a/, its status as a vowel, and as the first letter of a list called the alphabet." (p. 159) Posner et al, suggest that all the processes involved in letter processing are isolable subsystems and that there may be important psychological problems involved in passing control from one subsystem to another (e.g., from visual to auditory systems). They go on to suggest that "coordinating modality-specific subsystems may represent one explanation of the difficulty in the seemingly simple translation from a visual word to the word name." Such shifting between cross-modality subsystems clearly must go on under very fast time constraints. Probably the greatest time lag in reading occurs in the eye-voice span where often complex visual processing occurs considerably ahead of the auditory process of hearing the feedback of one's own voice (Levin and Kaplan, 1970). But even in reading aloud, much of the integration of audition and vision must go on nearly simultaneously (Levin and Kaplan, 1970).

It can be further argued, then, that a different paradigm is needed to index auditory-visual integration that is directly relevant to reading. The present research attempts to formulate an experimental paradigm that moves in that direction. Good and poor readers are simply presented with letters, one visual, one auditory, and asked to press a button if the two match, in letter names, and not to respond if they do not match. Such a task seems more directly to index the matching that initially goes on in learning alphabet letters and their appropriate sounds. It places virtually no emphasis on memory abilities. Also, since the task is so simple and surely basic to many of the activities performed early in elementary school, all children should be able to perform at perfect accuracy levels. The question of importance, then, becomes whether good and poor readers can perform the cross-modality matching task equally quickly. Again in light of its utter simplicity, as well as the enormous amount of practice the task receives, reaction time differences may be expected in Grade 1 good and poor readers but not in the older children.

Method

Subjects

Because no standardized reading tests are administered to children in Grades 1, 2, and 3 at the elementary school sampled, teachers were asked to list their "good" and "poor" readers and children were subsequently sampled from these groups. Eight good and eight poor readers were randomly selected from the pool provided by the teachers' ratings.

Stimuli and Apparatus

The lower case letters a through h served as the letter stimuli. Slides were made of the letters and presented on a back-lighted screen approximately 30 cm in front of the subject. The letters distended approximately 1.4 degrees of visual angle when observed at that distance. Auditorily the letters were spoken over a single channel of a Sony stero taperecorder. Nearly simultaneous (±50 msec) presentations of the auditory and visual stimuli were effected by a modified Kodak Carousel sound synchronizer. A pulse on the second channel of the taperecorder was converted by the synchronizer to a pulse which moved the slide projector ahead and initiated a Standard Electric timer. The subject's button press on positive-response trials turned the timer off. On no-response trials, a button press by the experimenter turned the timer off.

Procedure

Each subject was carefully instructed about the task and then presented with 10 practice trials. All subjects exhibited understanding of the task by the end of the practice trials. The task always involved pressing the response button if the letters presented auditorally and visually were letter-name matches. If they did not match, no response was required.

Immediately after the practice trials, the subject was presented 50 recorded trials, including 31 positive-response and 19 no-response trials. Subjects were repeatedly instructed to respond as quickly as possible, but to make no errors.

Subjects were tested individually in a quiet room in the elementary school.

At the end of the testing session they were thanked for their excellent performances. Each testing session required approximately 15 minutes.

Results

Error percentages for all groups were low, as can be seen in Table 1. Poor readers made only slightly more errors than good readers.

The mean reaction times for good and poor readers in the three grades tested are shown in Figure 1. The results of a two-way analysis of variance for these data points are shown in Table 2. As can be seen, reading level was a significant main effect, but grade was not. The interaction between grade and reading level was not statistically significant.

It is important to note that the difference in good and poor readers' reaction times does not decrease across grades, but rather increases. Poor readers in Grade 1 average 124 msec slower than good readers. In Grade 2 the difference increases to 252 msec, and in Grade 3 the difference is 281 msec.

Discussion

In that grade is not a statistically significant variable in the present study, it can be argued that children even in Grade 1 are, except for some minor fluctuations, near to asymptotic performance on the cross-modality matching task. This conclusion is especially plausible in view of the simplicity and basic nature of the task. The fact that poor readers are considerably slower than good readers in even this apparently simplest of tasks is especially disturbing if the poor readers have indeed reached an asymptote in performance. It is not reasonable in this case to hypothesize that boredom with the task led to lowered performance by the poor readers, in that they showed good motivation toward and attention to the task throughout the testing session. And, although not statistically significant, their mean reaction time is more than 80 msec slower in Grade 3 than in Grade 1. It is difficult to believe that such a low level performance would be exhibited by the poor readers, but the implications of the finding are great. If so much difficulty is associated with simple auditory-visual integration, it is easy to conceive of the high level of difficulty that will be associated with the more complex integration tasks that must be performed in efficient reading.

An important methodological point should also be made in view of the results of the present study. Error rates (or alternatively, percentage of correct trials) which are generally used as a main index of children's information-processing performances, do not discriminate at all between good and poor readers in this auditory-visual integration task. It is only when the reaction times are examined that the differences become visible. The striking nature of the lack of comparable efficiency on the part of poor readers on even the simplest auditory-visual integration task imaginable indicates a clear need for further studies of basic information-processing abilities in beginning readers using the more sensitive reaction-time measure.

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Table 1

Mean Probability of a False Alarm

for Good and Poor Readers

Grade	Poor readers	Good readers
1	.02	.01
2	.01	.00
3	.02	.00

Table 2

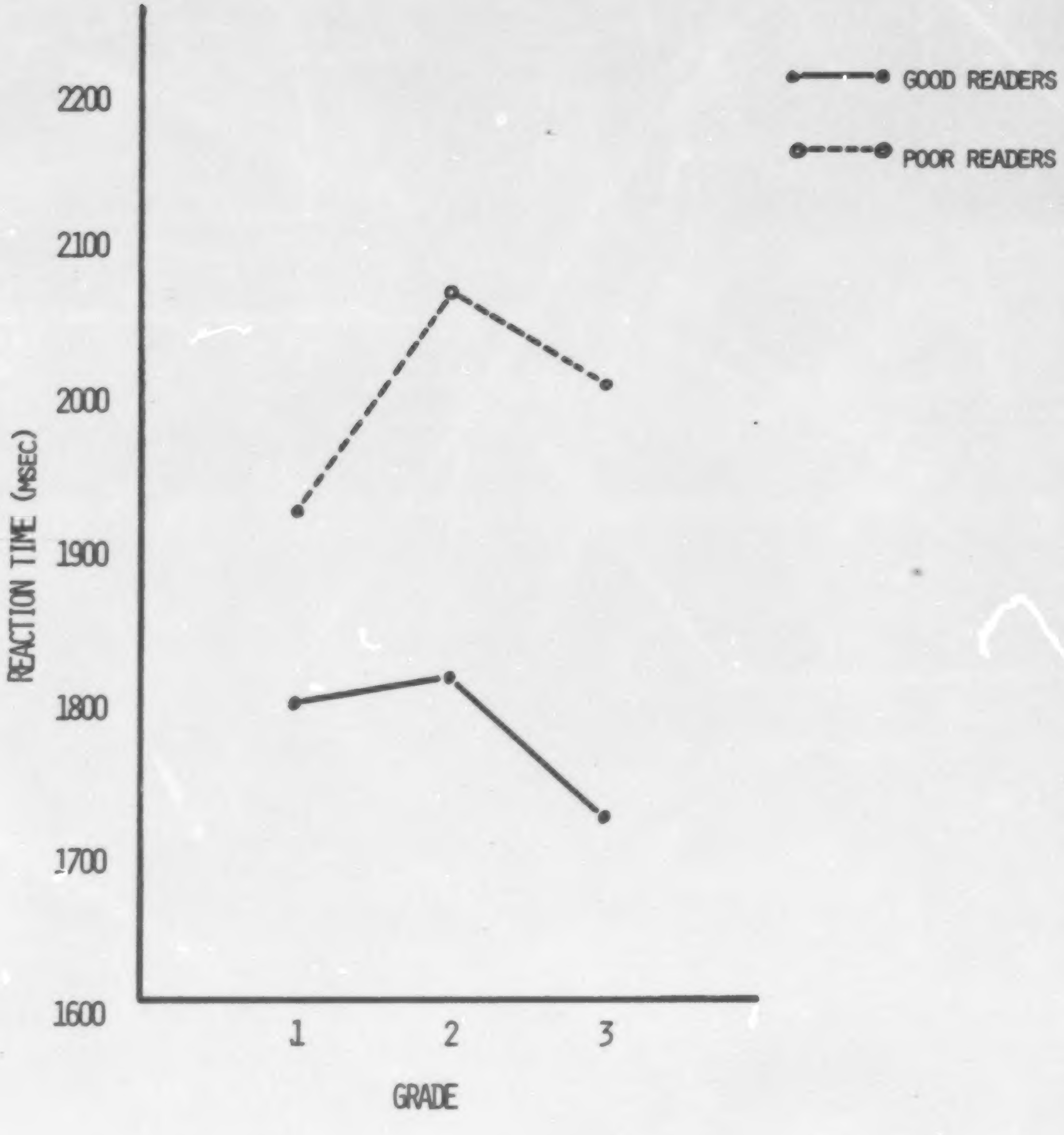
Summary of Analysis of Variance

for Grade X Reading Level

Source	df	MS	F
Total	47		
Reading level	1	574438.0	14.4[1]
Grade	2	33114.6	.83
Reading level X Grade	2	27535.7	.69
Error	42	39810.3	

[1] Significant at $p<.001$

FIGURE 1: REACTION TIMES OF GOOD AND POOR READERS ON THE AUDITORY-VISUAL MATCHING TASK



Experiment 5

Switching Between "Meaning" and "Letter" Levels of Processing--Differences in Good and Poor Readers

There is clear evidence that poor readers exhibit difficulties with numerous perceptual components thought to be involved in learning to read, or in mature, efficient reading itself. For example, Edelstein (1971) showed that good readers show more accurate perception of time than poor readers. Reilly (1971) demonstrated better auditory-visual integration in good readers. Spring (1971) showed that in matching capital letters, good readers were faster than poor, and in further analyses of his data, concluded that poor readers in the second half of trials in training sessions had slower central-processing components in the matching task.

Guthrie (1973) suggested differentiating the developmental reading literature into two kinds of models, assemblies and systems. An assembly model hypothesizes that perceptual components of the reading process develop independently and that poor readers should show weakness in one or two components but not in all of them. A system model hypothesizes that perceptual components of reading are interdependent, and that poor readers should therefore show deficits in nearly all reading subskills, and good readers should be strong in nearly all reading subskills. In examining reading skills on the 15 subsets of the Kennedy Institute Phonics Test, Guthrie was able to demonstrate the prediction from the system model was upheld.

Further demonstration of the interrelation of perceptual components involved in reading is reported by Jeffrey and Samuels (1967). They showed that kindergarten children could be taught to decode new words if they had acquired three perceptual skills -- left-to-right visual scanning, letter-sound correspondences, and blending of sounds into words. Samuels (1973) suggests this finding provides strong evidence for existence of a hierarchy of perceptual skills involved in reading.

It seems then, that the reading process can be broken into perceptual components which can be studied independently, but which are probably closely interwoven together in the actual process of reading. The present study, therefore, attempts to examine one way in which components of reading are combined, that is, "switching attention" between "levels of processing." These two concepts must first, however, be carefully defined.

"Levels of processing" is a concept which was defined and then empirically demonstrated by Posner and Mitchell (1967), Posner (1970), and LaBerge (1971). Posner and Mitchell, for example, showed that reaction time to classify pairs of stimuli as the "same" depends on whether that match is to be made structurally (A matches A), according to letter names (A matches a), or matching vowels (a matches o). Structural matches require the least time, vowel matches require the most time. Posner hypothesizes the latency differences result because the tasks must be carried out at different levels of abstraction, and at each level the information required before the answer can be given, is somehow greater. LaBerge showed in an analogous way that the latency of response to a particular stimulus depends on how similar the catch trials are to it. For example, the latency of response to an orange light becomes slower as S̲ must differentiate it from (1) a tone; (2) a green light; and (3) a red light. Again, both the amount and type of information necessary for the discrimination changes with each of the three kinds of catch trials. Although the changes in amount and type of information may form a continuum, for simplicity it has been assumed (Posner, 1970) that various discrete levels of processing are involved.

Finally, the concept of "attentional switching" must be examined. Again, Posner (1970), LaBerge, Van Gelder, and Yellott (1970), and LaBerge (1973a, 1973b) have provided operational definitions for the concept. Usually a cue is used to prepare S for an upcoming stimulus. In most cases that stimulus occurs, but occasionally an unexpected stimulus which also must be responded to, occurs. For example, LaBerge (1971) presented a 1000-Hz tone as a cue, and on most trials, it was followed by a 1000-Hz tone as a stimulus. On a small percentage of trials, however, an orange light appeared as the cue and also required a response. It was clearly the case that responding to an orange light when prepared for a 1000-Hz tone produced a much greater latency than when S was actually prepared for the orange light.

Essentially then, the cueing technique allows preparation of the S for a particular stimulus and therefore provides an opportunity to examine attentional switching from "preparation for x" to "response to y."

Reading involves component perceptual processes and it also involves moving from one component to another -- from attention to auditory modalities to attention to visual modalities; from processing of letters to processing of words; and from processing letters and combinations of letters to processing meaning. The present study examines this third kind of attentional switching from letters to meaning, and from meaning to letters.

The evidence about letter processing in poor readers is unclear. For example, Katz and Wicklund (1971) showed no latency or accuracy differences between good and poor readers in scanning for letters. However, Spring (1971) showed that poor readers were slower in matching letters. The research reported here requires a slightly different letter skill, namely matching two letters to each other, and compares the latency of response by good and poor readers. It also examines the latency required to match a word to the appropriate line drawing (a meaning-level match). Finally, it examines the latency of good and poor readers to switch from the letter task to the meaning task and from the meaning task to the letter task.

Method

The present method of manipulating levels of processing was to have each S respond with a button press if either two letters were exactly the same (a - a, m - m, c - c, e - e) in "letter" blocks, and to respond if a three-letter word matched a line drawing in the "meaning" blocks. The words used were bat, pan, car, and cap.

In "meaning" blocks, there were 30 trials. Sixty-seven percent of the trials were meaning matches, 13 percent were meaning nonmatches (catch trials), 13 percent were switch trials where Ss were to respond to a letter match, and 7 percent were letter nonmatches (switch catch trials). It was assumed that the type of trials most frequently presented would be prepared for on every trial, and Ss were, in fact, instructed to do so. There were 30 trials in the "letters" block, divided up in the same way. Before each of the 30-trial blocks, there were 5 practice trials, containing 3 matches, 1 catch, and 1 switch. The letter-trials and meaning trials were always run in 30-trial blocks to avoid instructional confusion on the part of the S's. The cue-stimulus contingencies for letter and meaning blocks are shown in Table 1.

Insert Table 1 about here.

There were two separate orders of the letter and meaning blocks, and these orders as well as the order of the two types of task were counterbalanced across subjects.

Subjects

There were two groups of subjects, including good and poor readers. Children were grouped according to teachers' divisions into reading groups.

There were five children randomly chosen from both reading levels from each of Grades 1, 2, and 3.

Apparatus

Each stimulus pair was presented on a slide, rear projected at a distance of 18 inches onto a screen. The projected size of the letters and words was approximately 3/4 inch and the child viewed the screen from a distance of approximately 18 inches. Opening of a tachistoscopic shutter in front of the projected slide initiated a Standard Electric timer and S's lever press turned the timer off. The slides were changed manually between each trial by E. The latency was read from the timer and recorded, and the timer was then manually reset. The subjects were run in a quiet room in the school.

Procedure

The subjects, who had previously received extensive experience in reaction time experiments, were instructed as follows for the meaning blocks and similarly except for appropriate changes for the letter blocks.

> "Whenever the word is the same as the picture, press the button as fast as you can. If the word does not match the picture, just let it go. Nearly all of the time I will show you the words and pictures but every once in a while you will see two letters. If both letters are the same, push the button. If they are different, let them go. Respond as fast as you can on the words and pictures."

If the child showed difficulty on any of the five practice trials, additional trials were given until it was clear the child understood the task. Any latency greater than three seconds was omitted and that trial was added at the end of the block. Blocks containing more than three errors were retested.

Results

Latencies for the two reading levels across the three grades are shown in Figure 1. For both preparation and switch conditions in both letter and meaning blocks, the poor readers at each grade show longer latencies. The results of a 4 x 3 x 2 analysis of variance are shown in Table 2. The data were divided into four tasks - letters prepared for, letters to meaning switches, meanings prepared for, and meaning to letters switches. There were three grades, and two reading levels in each grade. The analysis of variance shows significant main effects for reading level, grade, and task, and a significant interaction between task and reading level.

Insert Figure 1 about here.

Insert Table 2 about here

The difficulty of switching to a level of processing can be ascertained by comparing the latency to process letters (or meanings) when there is preparation for the letters (or meanings) to the latency to letters (or meanings) when an attentional switch had to precede the processing. This analysis is shown in Figure 2.

Insert Figure 2 about here.

As can be seen in Figure 2, in Grade 1, poor readers have more difficulty than good readers switching from meaning to letters, but good readers have more difficulty than poor readers in switching to meaning. It should be noted, however, that the poor readers' latencies to meaning matches are so long that a possible ceiling effect may mask any further difficulty in attentional switching to the meaning task from the letter task.

In Grade 2, poor readers have less difficulty switching to letters than do good readers, but they have more difficulty switching to meaning tasks from letter tasks. In Grade 3 there is no large difference in the time taken by either group to switch from the meaning to the letter task. Poor readers, however, still have greater relative difficulty switching from the letters to the meaning task.

The error rates for Letter Blocks and Meaning Blocks are shown in Table 2. As can be seen, the poor readers consistently made slightly more errors than good readers.

Insert Table 3 about here.

Discussion

As shown in the present experiment, poor readers are not only considerably slower in tasks where they have to match letters, or match a word to a corresponding picture, but they also show significant relative slowing when they have to switch attention from letters to meaning.

As stressed by Samuels (1973) a child must, to become a good reader, not only discriminate accurately among letters, but he must be able to do so with little or no conscious attention. Otherwise he will never be able to free his attention to work at a meaning level. In the results reported here, even third grade poor readers were barely faster on matching letters than first grade good readers. In other words, they were only then reaching a processing speed that might indicate the kind of automaticity in processing letters that Samuels discusses. These readers without automaticity in letter discriminations cannot then, even in the third grade, show as fast a meaning-level latency as first grade good readers - as is demonstrated by comparing prepared-meaning latencies for poor-third grade and good-first grade readers.

As is expected by the systems model of reading, poor readers show difficulty, relative to good readers, in not only processing at letter and meaning levels, but in switching from one level to the other. Unexplainably, both good and poor readers are slightly slower in the preparation and switch tasks in Grade 3 as in Grade 2. Since throughout acquisition of reading, the young reader must switch down to the letter level to handle new words, then move back up the meaning level, one would expect continued improvement in the speed of shifting. It would be especially interesting to examine responses from slightly older children to see whether the third grade loss is only a plateau before increased shifting efficiency is acquired.

An additional question that seems important to ask next is whether the long reaction times required for shifting by the poor readers result from difficulty in taking attention away from the current level of processing or in moving into the level of processing to which the switch must be made. The present data do not allow such a discrimination to be made.

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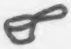
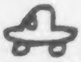
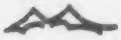
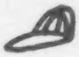
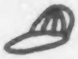
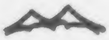
TABLE 1

Cue-Simulus Contingencies for a) Letter-Matching Blocks and b) Meaning-Matching Blocks

a) Letter-Matching Block

Stimulus	Response	Frequency	
a-a	yes	5	preparation trials
m-m	yes	5	
c-c	yes	5	
e-e	yes	5	
a-m	no resp.	1	catch trials
c-e	no resp.	1	
c-m	no resp.	1	
a-e	no resp.	1	
pan - 	yes	1	switch trials
car - 	yes	1	
bat - 	yes	1	
cap - 	yes	1	
car - 	no resp.		catch trials
pan - 	no resp.		

(Table I cont.)

b) Meaning-Matching Block

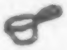
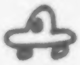
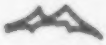
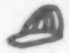
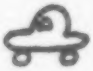
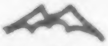
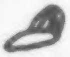
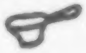
Stimulus	Response	Frequency	
pan – 	yes	5	preparation trials
car – 	yes	5	
bat – 	yes	5	
cap – 	yes	5	
pan – 	no resp.	1	catch trials
car – 	no resp.	1	
bat – 	no resp.	1	
cap – 	no resp.	1	
a-a	yes	1	switch trials
m-m	yes	1	
c-c	yes	1	
e-e	yes	1	
m-c	no resp.	1	catch trials
e-a	no resp.	1	

TABLE 2

Summary of an Analysis of Variance for
Grade x Task x Reading Level

Source	df	MS	F
Between Ss			
Reading Level	1	2.76	13.84***
Grade	2	1.88	5.45**
RXG	2	.29	1.46
error (a)	24	.20	.00
Within Ss			
Tasks	3	.77	13.01***
T x R	3	.19	3.28*
T x G	6	.12	2.03
T x G x R	6	.08	1.35
error (b)	72	.06	.00

* p < .05
** p < .025
*** p < .001

TABLE 3

Error Rates for Letter-Matching and Meaning Matching Blocks for Good and Poor Readers

	Poor Readers			Good Readers	
	Average % Errors in 30 Trials			Average % Errors in 30 Trials	
Grade	Letter-Matching	Meaning Matching	Grade	Letter-Matching	Meaning Matching
1	5%	2%	1	3%	2%
2	5%	5%	2	3%	4%
3	4%	8%	3	4%	5%

Figure 1: Latencies for Letters Meaning Switches and Meaning Letters Switches for Good and Poor Readers

Figure 2: Latencies for Letter-Matching (Preparation and Switch Trials) and Meaning Matching (Preparation and Switch Trials) for Good and Poor Readers

Fig. 1

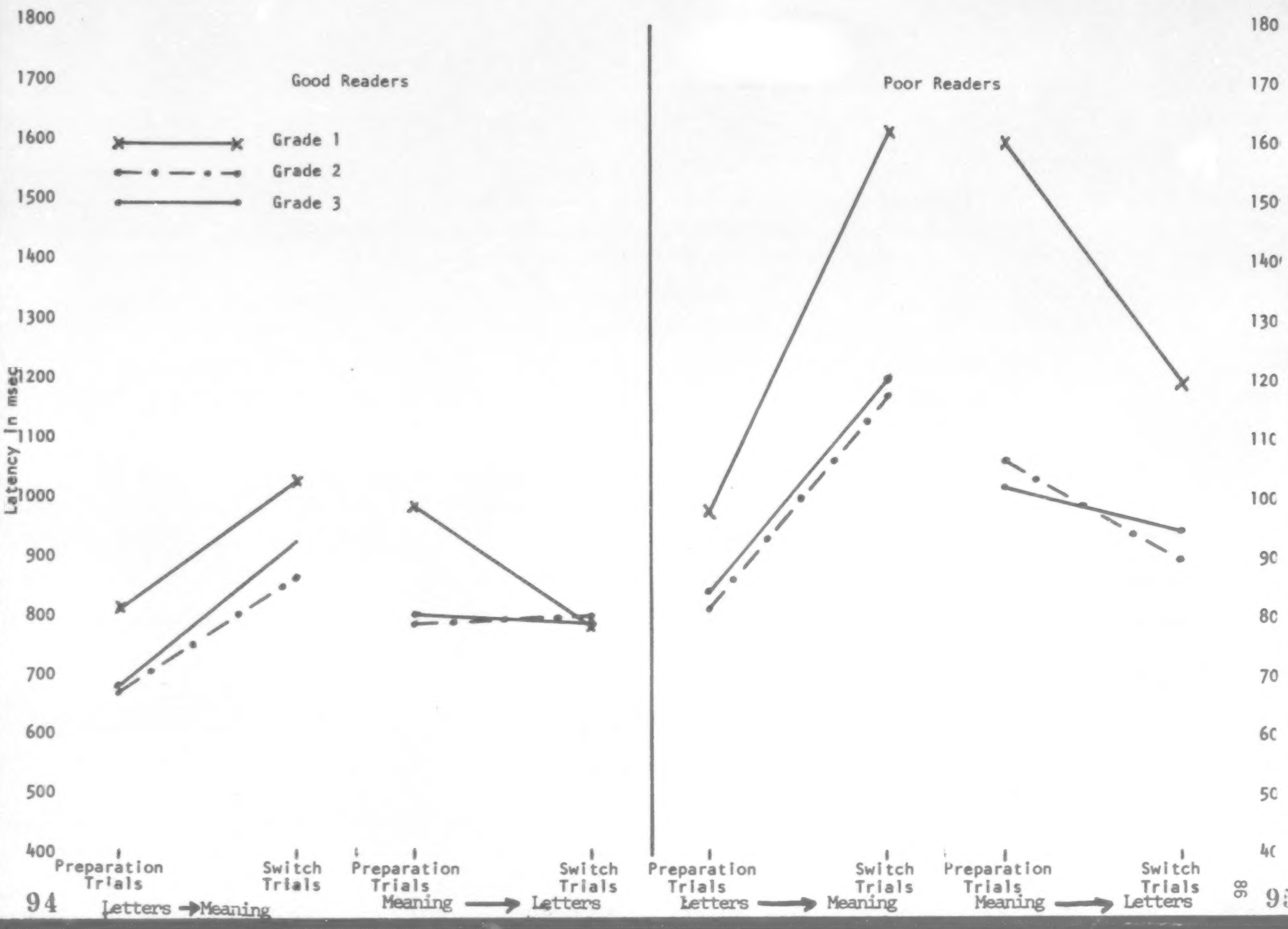
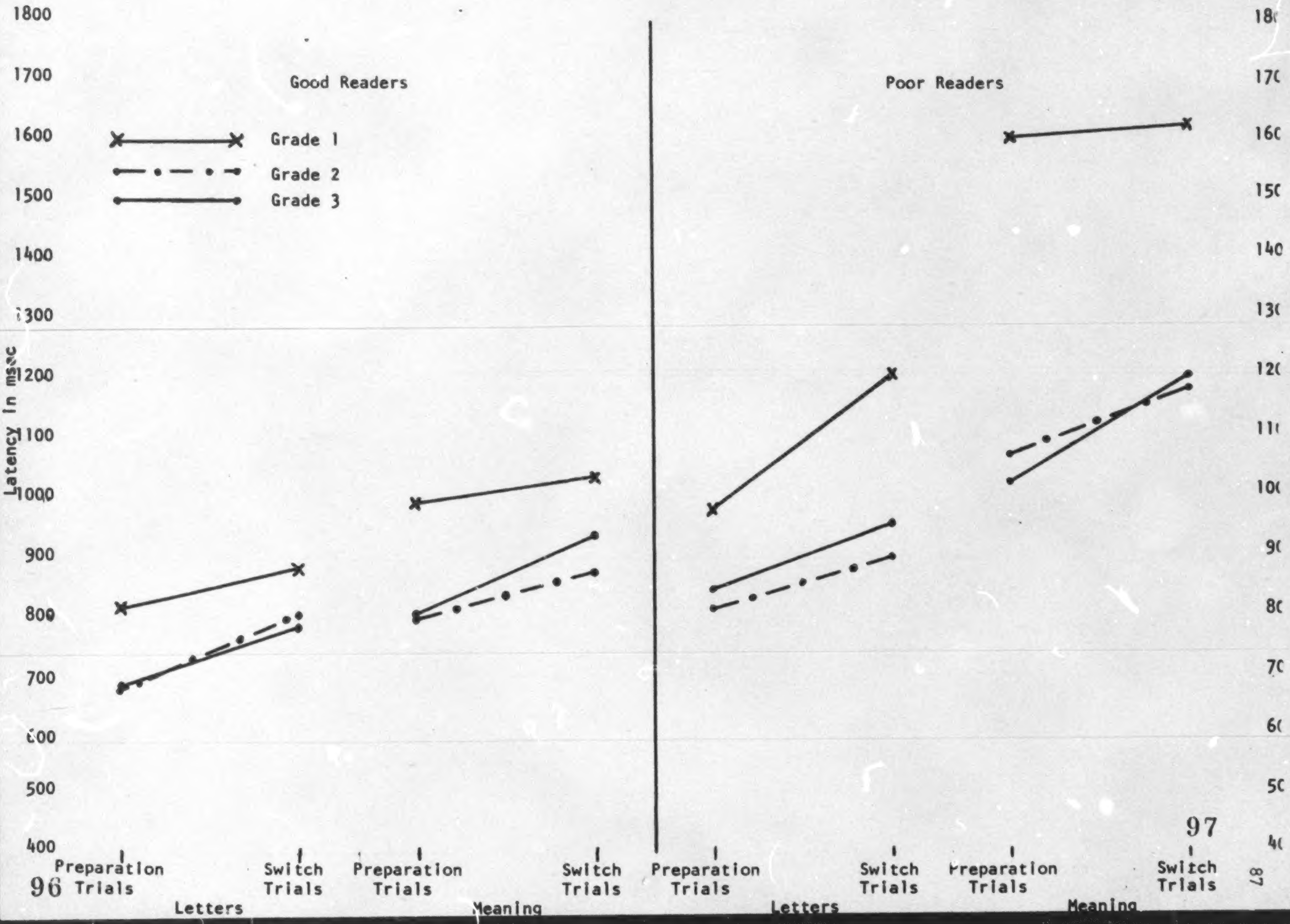

Good Readers
Poor Readers
Grade 1
Grade 2
Grade 3
Latency in msec
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
Preparation Trials
Switch Trials
Preparation Trials
Switch Trials
Letters → Meaning
Meaning → Letters
Preparation Trials
Switch Trials
Preparation Trials
Switch Trials
Letters → Meaning
Meaning → Letters

Fig. 2


Good Readers
Poor Readers
Grade 1
Grade 2
Grade 3
Latency in msec
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
Preparation Trials
Switch Trials
Preparation Trials
Switch Trials
Letters
Meaning
Preparation Trials
Switch Trials
Preparation Trials
Switch Trials
Letters
Meaning

Experiment 6

Discriminative Processing of Line Orientation by Good and Poor Readers

(A Replication and Expansion of Experiment 1)

The present study is concerned with differences between good and poor readers in discriminating line segments at various orientations. Though admittedly only one of the many possible distinctive attributes of letters, orientation (or slant) of lines has proved theoretically important in at least three separate areas of inquiry: (1) in neurophysiological psychology; (2) in perceptual psychology; and (3) in cognitive psychology. The importance of distinguishing orientation in each of these areas will be briefly examined below. First, however, it is necessary to note that there exists theoretical difficulty in the very defining of orientation, and certainly in comparing ability to discriminate orientations across various tasks or contexts in which the discrimination must occur. As an example of problems in defining orientation, Pufall and Shaw (1973) point out that any orientation can be considered either topographically (properties of figures, unaffected by any deformation without tearing or joining) or geometrically (relational properties of solids, surfaces, lines, and angles). As examples of task discrepancies in determining difficulty of orientational discriminations, first, MacKay, Brazendale, and Wilson (1972) showed that the relative difficulty of drawing horizontal and vertical lines (for six to nine-year-old children) depended upon what kind of drawing required the lines. In Figure 1 taken from their study, the horizontal lines to be drawn in A are better produced than the vertical lines needed in C. The horizontal lines in B, however, are not as well-produced as the vertical lines required in D. Also demonstrating the effect of context in determining difficulty of defining difficulty of discriminating orientations, Strayer and Ames (1972) showed that preschool children produced different performance levels in discriminating forms made up of lines of various orientations, depending upon whether the child had to place the form in a position matching that just produced by the experimenter or whether the child had to copy the form. Finally, Olson (1970) reports similar task-specific performances by preschool children depending upon whether they must discriminately choose between obliques, and/or reproduce oblique lines. Throughout the analysis that follows, then, these definitional difficulties in discussing discrimination of line orientation will of necessity be continually considered.

Relevance of Orientational Discriminations: Neurophysiological and Comparative Psychology

In the tradition of Hubel and Wiesel (1959) and Lettvin, Maturana, McCulloch, and Pitts (1959), it has become clear that there exist neural cells differentially sensitive to orientation. In the cortex of kittens (Pettigrew, Nikara, and Bishop, 1968) there is evidence that cells responsive to vertical and horizontal orientations are, in fact, more numerous than cells responsive to other orientations. Maffei and Campbell (1969) showed in humans that evoked cortical potentials to horizontal and vertical orientations are greater than those to oblique lines. (Since the same was not true for electroretinograms, the authors inferred that the neurophysiological effect occurs post-retinally.) Both Hirsch and Spinelli (1970) and Muir and Mitchell (1973) found that raising kittens in isolation, except for stimulation of only one orientation during a period of either 10-12 weeks or for five months after birth, led to inability to discriminate other line orientations. Hirsch and Spinelli, in fact find that although a previous study (Spinelli and Barrett, 1969) had demonstrated with single-cell recordings from the visual cortex, that cells responding to obliques do exist in normal kittens, those raised in partial isolation (presented only horizontal lines to one eye and vertical lines to the other) showed no diagonal-responding cells. This effect seems, however, to be specific to phylogenetic level, in that Mize and Murphy (1973) did not get the same results with similarly isolated rabbits.

In addition to these direct neurophysiological findings there is behavioral evidence in several subhuman species that certain orientations are easier to discriminate than others. For example, Sutherland (1957) demonstrated that octopi can discriminate vertical-horizontal discriminations, but not diagonal ones. In humans, Goldstein (1967, 1968) showed that in stabilized images, diagonal lines are more likely to disappear than are horizontal or vertical lines. Wade (1972) showed that although there were no differences in fading in diagonals, verticals, and horizontals monocularly, there was more fading binocularly, of diagonals. Essentially, then, there is a suggestion from the physiological and comparative literature,of organismic advantage in dealing with vertical and horizontal orientations, and relative disadvantage for slanted orientations.

Relevance of Orientational Discriminations: Perceptual Psychology

In developmental perception studies there are findings consistent with the neurophysiological and comparative data. Rudel and Teuber (1963) showed very little difficulty with discriminations between horizontal and vertical lines in children 3 to 8 years old. But discriminating oppositely oriented diagonal lines was extremely difficult for 3-, 4-, and 5-year olds, becoming easier for 6-, 7-, and 8-year olds. Olson (1970) in an extensive study of ability to deal with diagonality showed that even though children aged 4 and 5 could discriminate diagonal lines, they generally could not reproduce a diagonal pattern of checkers on a checkerboard. Strayer and Ames (1972) demonstrated that although children had especial difficulty matching diagonally oriented shapes, with practice which encouraged attention to orientation, marked improvement was shown in drawing geometric figures containing diagonals (i.e., a rhombus and diamond). Interestingly enough, McGurk (1972) was able to show that infants as young as six months can discriminate orientation of lines. He suggests that it may be an adaptive strategy for registering object and shape constancy, for the infant to attend more to identity between different orientations of forms and leave orientation differences themselves relatively unattended.

Relevance of Orientational Discriminations: Cognitive Psychology

The problem of perception of orientation stretches also into the study of developmental cognition. Actually, as Olson (1970) and others point out, perceptual and cognitive processes are probably part of a continuing analytic process, and the distinction is maintained largely for pragmatic reasons. As mentioned previously, Mackay, Brazendale, and Wilson (1972) in examining conservation tasks, suggest and then empirically demonstrate that abilities to draw horizontals or verticals appropriately largely depend on "difficulty" of the situation in which conservation must be carried out. Beilin, Kagan, and Rabinowitz (1966) previously suggested the same kind of notion, but had placed more emphasis on conceptual abilities than on perceptual ones. Although not a direct test of ability to discriminate orientation, Drummond, Williams, and Aiken (1973) showed that not perceptual strategies per se, but rather "cognitive" use of perceptual information differentiated sorting of patterns by second and fifth graders. Finally, Girgus (1973) argued that in discriminating orientational as well as other features of patterns presented one view at a time, it may be necessary for the child to store "information between trials" and to build the distinctive features into an "overall schematic map"(p. 372). Clearly these kinds of evidence indicate that "central processing" is an important intervening event to consider when examining discrimination of various orientations.

Orientation, then, is an interesting and problematical kind of distinctive feature to examine. If it is assumed that poor readers are poor at least partially because they lack efficiency in analyzing distinctive features, will it be the case that even with an elementary feature like orientation of line, they will show either slower processing or evidence of a "different" mode of processing? In an earlier study, the present author (Thorson, 1974) showed that good, medium, and poor readers, and college level readers do show differential reaction times to discrimination of three pairs of line-orientations in a Donders Type C choice discrimination task. All groups showed the most difficulty in discriminating lines slanted to the right 30 degrees and 45 degrees, and greatest ease with a discrimination of a horizontal and at 45 degrees slant to the right. The study did not, however, compare a sufficient number of orientation-pairs to allow thorough-going inferences about difficulty. The present research replicates the previous procedure, but adds five orientation-pairs to the total task for each subject. Also, because the "medium" readers' group seemed impossible to define clearly, and identify satisfactorily it was not included in the present study.

Method

Design

On each block of trials, one orientation (the "positive" stimulus) was to receive a button-press response, and the other (the "negative" stimulus) was to receive no response. Five line orientations were used in the pairs: (1) horizontals (0 degrees); (2) verticals (90 degrees); (3) oblique, 45 degrees to the right; (4) oblique, 30 degrees to the right; and (5) oblique, 45 degrees to the left. The pair combinations used were as follows (the positive-stimulus orientation is listed first): (90 degrees-0 degrees), (0 degrees-45R degrees), (90 degrees-45R),(45R degrees-0 degrees), (45R degrees-90 degrees), (45L degrees-45R degrees), (45R degrees-45L degrees), and (45R degrees-30 degrees). Twenty-five trials of each kind of discrimination were tested for each subject. In each block of trials, 17 trials presented the positive-stimulus; eight trials presented the negative-stimulus. Order of positive and negative stimuli was randomized across the 25 trials. Presentation of the eight tasks were counterbalanced across subjects within each experimental group.

On each trial a cue was presented 500 msec before the stimulus appeared. The cue was always the same as the positive stimulus.

Subjects

Two groups of children were selected from each of Grades 1 through 3. In each grade eight children were randomly sampled from groups previously designated as "readers with severe difficulties" (poor), and "advanced readers" (good). The designations were made for the school reading program on the basis of teachers' ratings. In addition, eight college students with no known reading deficit were tested on all eight tasks.

Materials and Apparatus

The stimulus lines for the three tasks were presented by IEE readout tubes with 2" x 2" screens. Preceding the stimulus line by 500 msec there was flashed on the screen a cue which on all trials matched the positive stimulus. The subject responded to a single button 5 inches to the right of the IEE readout screen and at a tilt 20 degrees from the vertical. Onset of the line stimulus in the screen initiated onset of a Standard Electric timer. A button press from the subject produced stimulus offset and stopping of the timer. Order of positive and negative stimuli was controlled by hand by the experimenter who was situated beside the subject.

Response times were recorded manually from the timer and the timer was reset before each trial.

Procedure

Each subject was tested individually, the grade school children in a quiet room in the elementary school, the college students in a laboratory room in the University psychology department. Each subject sat approximately 30 cm in front of the stimulus-presentation screen, and was instructed to keep his index finger on the response button at all times.

The eight orientation-pair tasks were tested at two times in order to avoid fatigue effects. All subjects received five practice trials of the task before each block was tested. Also, before each task the experimenter showed the subject the two different lines that would be used, explained which one he should respond to. If the subject did not show satisfactory understanding of the task after the five practice trials, additional trials were presented until the subject seemed to understand completely. No subjects were eliminated for lack of ability to perform the task. All subjects were instructed to respond as fast and as accurately as possible.

Results

Percentages of false alarms produced by the grade school sample for each of the experimental groups are shown in Table 1. As can be seen, poor readers made more errors than good readers only in Grade 1, and the differences are small. Only one subject required retesting of one of the orientation-pair tasks. Error rates for the college-level readers are shown in Table 2. None of these subjects required retesting because of unacceptably high false alarm rates.

The summary of a three-way analysis of variance for the grade school reaction times is shown in Table 3. There are significant main effects for reading level and task, but not for grade. None of the interactions are significant. In the analysis of variance performed on the reaction times of the adult sample, task also produces a significant effect ($F(7,63) = 3.70$, $p<.005$).

Duncan's multiple range test was used for multiple comparisons among the eight tasks for both the younger and college samples. Significant R values were obtained as shown in Table 4. From these multiple comparisons, then, it can be seen that for all groups, except good readers - Grade 2, Task 8 produces significantly longer reaction times than at least Tasks 1 and 2. For the poor readers, however, Tasks 6 and 7 also produce significantly longer reaction times than some of the other tasks.

Discussion

The neurophysiologically, cognitive, and perceptually-oriented approaches to the study of processing of line orientations predict that developmental differences should occur, at least in comparing young children and adults. These differences are clearly supported here in both the false alarm rates, and in the reaction times. College-level subjects are faster (by at least 500 msec) and more accurate than the younger subjects. Discriminations involving slanted lines produce little difficulty for college-level subjects, except when two lines slanted in the same direction have to be discriminated (Task 8). For the younger subjects, good readers show the same difficulty also in discriminating lines slanted in opposite directions (Tasks 6 and 7). It is important to note that younger children show considerable reaction time variations across the eight tasks. College-level readers, however, show almost exactly the same reaction time for all the discriminations except that of Task 8. This result may point in the direction of development of what LaBerge (1973) and Posner and Snyder (1974) call "automaticity" of processing. What this means is that the distinctive features of stimulus forms which are necessary to detect that they are different require an asymptotically small amount of time to bring into "attentional readiness." LaBerge (1973) points out this phenomenon by showing that even when subjects are prepared to respond to another task and suddenly presented with a letter discrimination, they are as fast on that discrimination as when they are specifically prepared for it. Posner and Snyder (1974) document that familiar discriminations can occur without any loss of speed, even when another task is being processed simultaneously. The present study shows that regardless of what line orientations are to be discriminated (except in Task 8), college-level subjects show very fast, and equal latencies. The younger readers are much slower, and the variation in reaction times across the tasks shows that automaticity as indexed in asymptotically low reaction time across the tasks, could not possibly be occurring. This finding is striking in that the line-orientation task seems one of basic simplicity.

A final point important to make, is that comparisons of younger good readers and older poor readers does not yield the similarities expected under a "developmental lag" hypothesis. In other words, Grade 1 good readers do not show the same pattern and general speed of reaction times that poor readers do even in Grade 3. Unless the lag is greater than two years, it is not accurate to say poor readers process like younger good readers. In view of the present results, a reasonable hypothesis is that poor readers are not developing automaticity in processing of even the simplest set of discrimination tasks as was tested here. Substantiation of such an hypothesis will require tapping good readers at ages younger than six years, and following the pattern of latencies for poor readers through levels above Grade 3.

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Table 1

Mean Probability of a False Alarm Error for the Eight Orientation-Pair Tasks (Grade School Readers)

	Tasks								
Grade	1	8	6	7	2	4	3	5	Mean for all the tasks
				Poor Readers					
1	.09	.13	.19	.16	.11	.13	.08	.13	.13
2	.09	.08	.06	.09	.08	.09	.11	.05	.08
3	.09	.09	.03	.17	.05	.05	.08	.05	.08
				Good Readers					
1	.03	.14(1)	.11	.06	.06	.05	.08	.03	.07
2	.09	.16	.14	.08	.06	.03	.03	.02	.08
3	.02	.13	.06	.11	.02	.03	.05	.08	.06

Note. The number in parentheses refers to the block which had to be retested because of an unacceptable error rate.

Table 2

Mean Probability of a False Alarm Error for the Eight Orientation-Pair Tasks (College-Level Readers)

Tasks								
1	2	3	4	5	6	7	8	Mean for all tasks
.00	.03	.02	.02	.05	.08	.00	.00	.03

Table 3

Summary of an Analysis of Variance for

for Grade X Reading Level X Task (Grade-School Readers)

Source	df	MS	F
Between	47		
Reading level	1	2081080.0	13.19[1]
Grade	2	2862.4	.02
Reading level X Task	2	36817.1	.23
Error (a)	42	157757.0	
Within	336		
Tasks	7	90872.1	5.65[1]
Level X Tasks	7	23534.7	1.46
Grade X Tasks	14	17322.9	1.08
Level X Grade X Tasks	14	13146.7	.82
Error (b)	294	16092.5	

[1] Significant at $p<.001$

Table 4

Significant R-values for Duncan's
Multiple-Range Test (Grade School and College-Level Readers)

Grade	Task pairs for which significant R-values were obtained
	Poor readers
1	(1,6), (1,7), (1,8), (2,8)
2	(1,8), (2,8), (3,8), (4,8), (5,8)
3	(1,7), (1,8), (2,8), (2,7)
	Good readers
1	(1,8), (2,8), (3,8)
2	No tasks significantly different
3	(1,8), (2,8)
	College-level readers
	(1,8), (2,8)

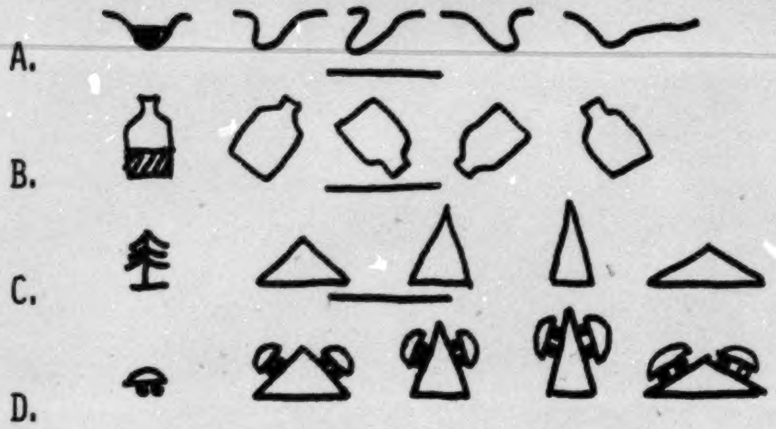


FIGURE 1: CONTEXTS IN WHICH CHILDREN HAD TO DRAW HORIZONTAL (A AND B) OR VERTICAL (C AND D) LINES. IN C CHILDREN HAD TO DRAW THE TREE ON THE MOUNTAINS. IN D CHILDREN HAD TO DRAW A MAN IN THE CAR.
(FROM MACKAY, BRAZENDALE, AND WILSON, 1972)

FIGURE 2: REACTION TIMES FOR THE LINE ORIENTATION TASKS (POOR READERS AND COLLEGE-LEVEL READERS)

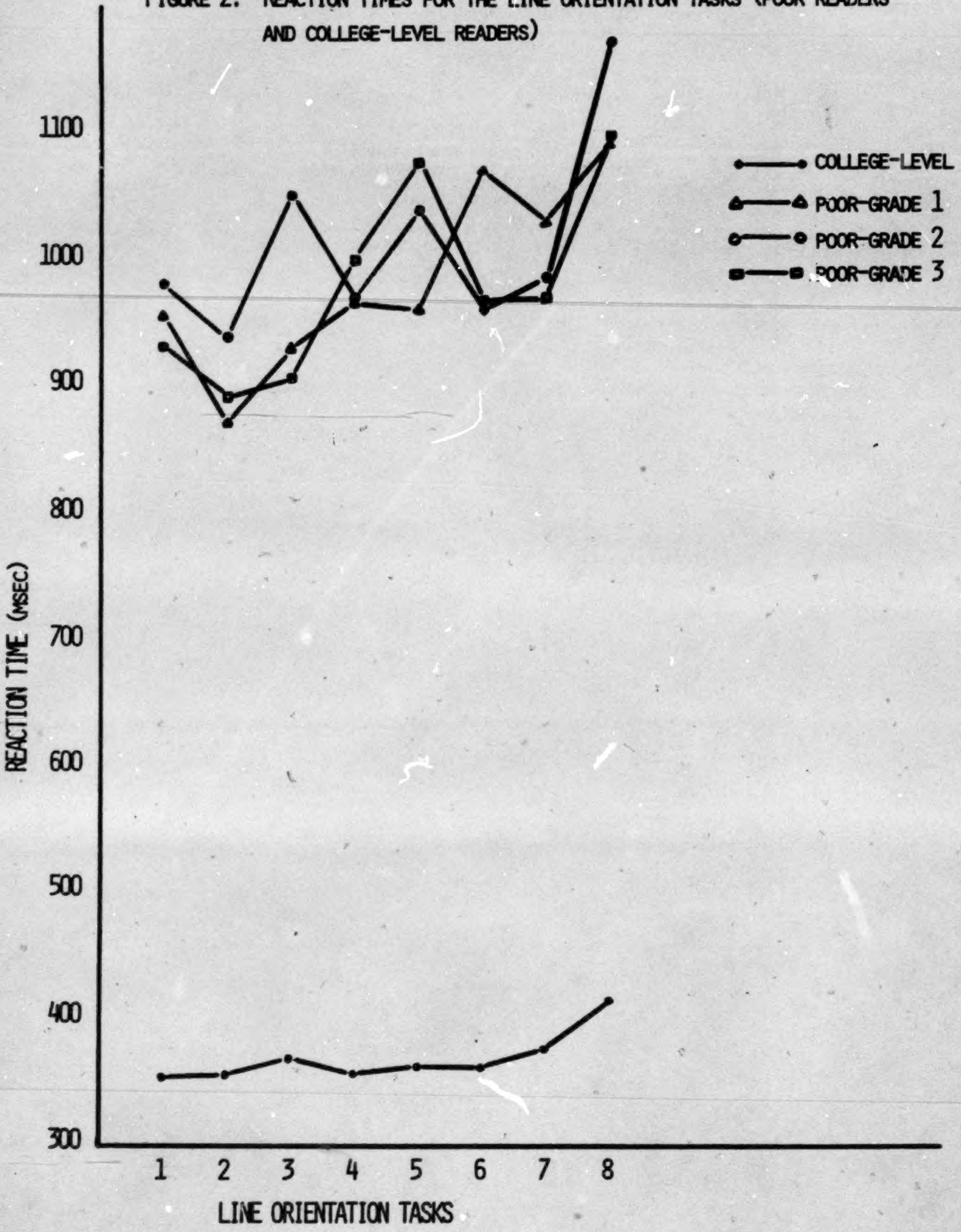
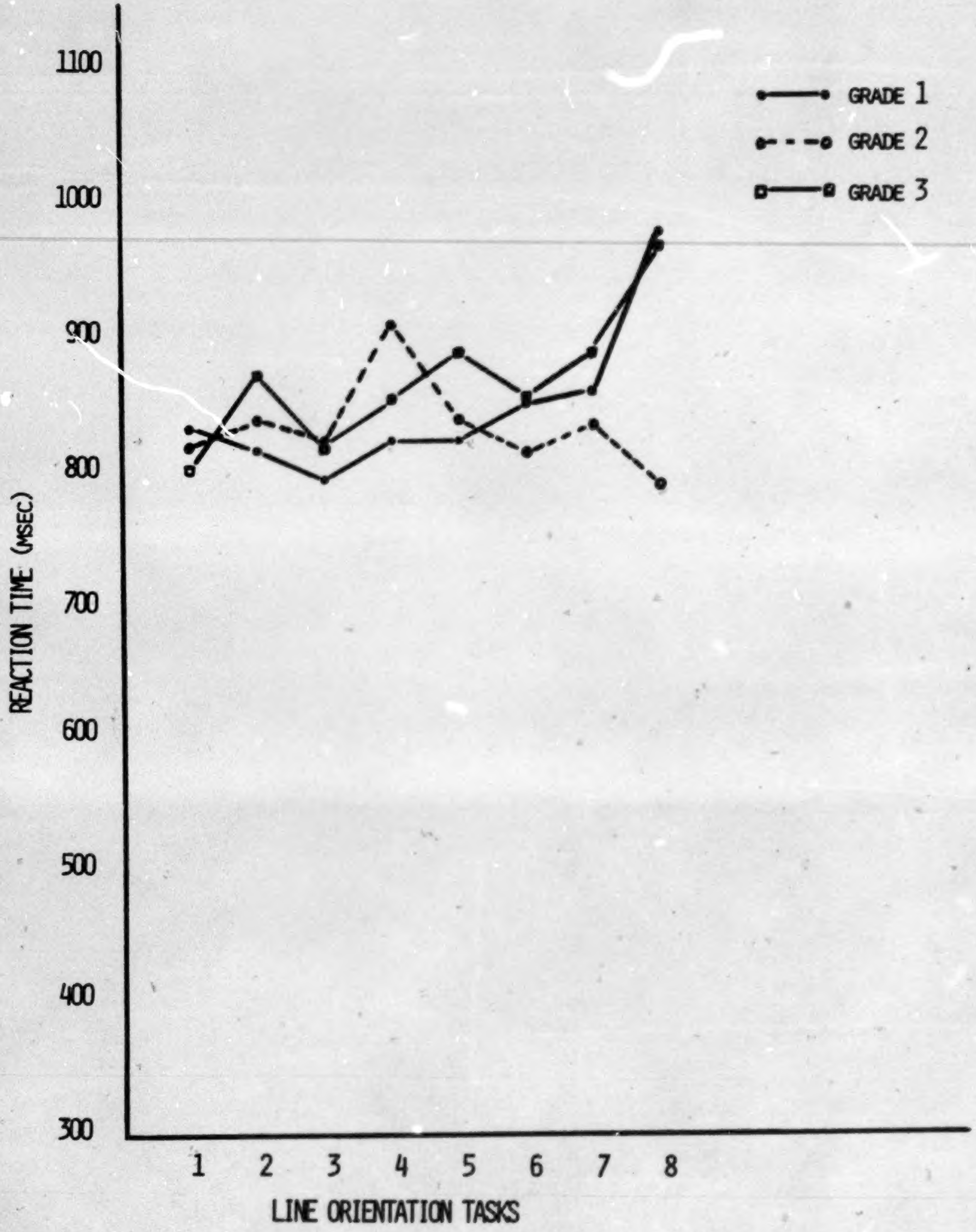


FIGURE 3: REACTION TIMES FOR THE LINE ORIENTATION TASKS (GOOD READERS)



FALL REPORT ON THE READING RESEARCH PROJECT

To: Participating teachers and administrators, Granville Elementary School

Date: Dec. 4, 1973

From: Esther Thorson
Assistant Professor
Department of Psychology
Denison University

Introduction:

As you know, Jane Holloway has been testing children in the 1st, 2nd, and 3rd grades on certain perceptual tasks. Your cooperation and suggestions have been invaluable to our work. Because your support, understanding, and ideas are so important to our progress, we hope to explain briefly in this report what we have done so far and what the next step will be. A previous report examining immediate practical applications of this research was sent out to all teachers last spring and is available to any who are interested.

The Research and its Purpose:

Although there are at present many tests (e.g., ITPA, Stanford Diagnostic Reading Test, Metropolitan Readiness Test) which can distinguish a child with reading difficulties from one who is progressing satisfactorily, there has been little work done toward developing a test of basic perceptual processing characteristics of efficient and poor readers. If we had a reliable screening device which could detect at an early age those children who would most likely experience difficulties in learning to read, these children could be given a variety of perceptual-motor training tasks in the hope of providing them with some useful remedial help. The research being done at the elementary school now is aimed at developing just such a screening device. The questions are: (1) What tasks will best screen processing characteristics; and (2) Can we discover processing modes that are clearly different in good and poor readers. This research program is supported by a grant from the National Institute of Education.

Experiment #1:

The Problem: This experiment, just completed, examined reaction times of poor, medium, and good readers to various combinations of diagonal, horizontal, and vertical lines. It has been suggested by a Piagetian psychologist, David Olson (1970) that discrimination of the diagonal is not a question of simple recognition, but rather an indication that the child has developed a system for perceiving figures in terms of certain critical attributes. Although children below the age of six or seven have difficulty differentiating the diagonal from lines of other orientations, Olson reports that most children above that age can handle the diagonal successfully. In other words, an important "critical feature," namely line orientation, is easily processed by children above Grade 1. In the present study it was hypothesized, however, that a highly sensitive measure of processing, reaction times to lines differing in orientation, will show remaining difficulty with the diagonal, above Grade 1, especially for poor readers.

Specifically, it is expected that poor readers will exhibit more errors than good readers, and will be much slower in differentiating between lines of various orientations. If poor readers are not only less efficient in processing orientation features, but are also doing their differentiations with different processing modes, the pattern of reactions times (as indexed by which orientation tasks are most difficult) they show will be different from fast readers.

Method:

To test the above hypotheses, the children in three groups, fast, medium, and poor reading, were asked to push a button when they saw the "yes" line light up in a screen, but not when the "no" line was presented. There were three tasks:

Task 1:	/	—	Task 2:	/	|	Task 3: \	/
	yes	no		yes	no	yes	no

Preliminary results:

Surprisingly, poor readers are not less accurate than fast readers in any grade, but medium readers are significantly less accurate than both the other groups in Grades 1 and 2.

[Question: Do you find medium level readers to be more "impulsive" than slow or fast readers?]

In terms of overall speed on the three tasks, there are no significant differences between good, medium, and poor readers in Grades 1 and 2. Major differences occur, however, in Grade 3 where good readers are faster than medium readers, and medium readers are faster than slow readers. This is especially interesting in that Olson would predict that by third grade there should be no differences in the three groups since the tasks should all be very well learned by that time. The result does support Jay Samuel's (1973) hypothesis about poor readers, namely that they never sufficiently "overlearn" the most basic, simple tasks underlying discrimination of letters. Because they remain slow in the basic sub-tasks, with addition of each increasingly complex reading skill, they fall further behind. Samuel's suggested remedy is simply practice, practice, and more practice on the most basic sub-tasks, like the one we gave the children.

Concerning patterns of latencies across the three tasks, there appear to be differences between good, medium, and poor readers, when the children's responses are pooled. (See Figure 1.) But within groups, the variance (variation) is enormous. It is here the greatest amount of work needs to be done. Further statistical analyses must be run before it is reasonably clear whether differing processing modes are appearing. It will also be helpful to compare the individual's responses in this experiment to those in the next two experiments.

The question of whether poor readers process differently, in addition to processing more slowly is an important one for understanding reading problems. It is at that question, of course, that this and the next experiments are aimed. Results from Experiment 1 indicate that different kinds of processing are a very good possibility.

Experiment #2:

The next experiment we want to run will allow comparison of how good and poor readers "put together" letters into meaningful words. We will be dropping the medium readers from this study because they appear to be too much a hetereogeneous group. The second experiment will also examine reaction times, but will cut down on the number of trials run so the whole session with each child will take only 10 minutes. To further decrease any inconvenience to the teachers, we are asking you to give us very specific information about when we should not take the children out of the classroom. A sheet for listing of your time preferences (if you have not already done so) is included at the end of this report.

In conclusion, results to date are very encouraging and we are excited about future possibilities. We do appreciate your help and cooperation. If you have any suggestions for procedure or hypotheses, please do not hesitate to speak to Mrs. Holloway, or to call me at 587-0810 (ext. 484). The suggestions we have received so far have been excellent, and several of them are incorporated into the second experiment.

We hope this information has been interesting to you. A thorough report and description of individual children's work will be sent out next spring.

Thank you very much.

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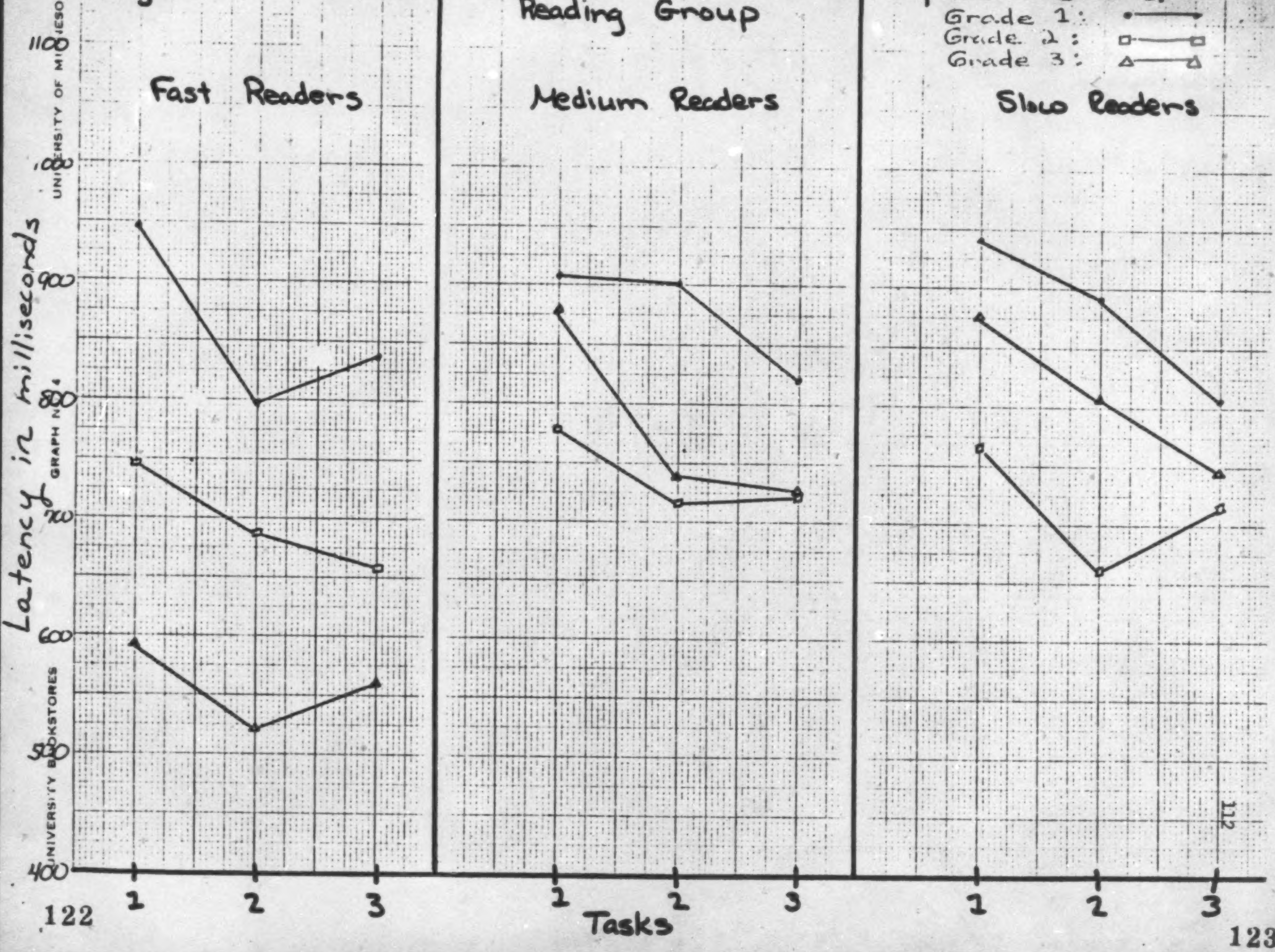
Figure 1: Mean Latencies as a Function of Grade and Reading Group



UNIVERSITY OF MINNESOTA
GRAPH No. 4
UNIVERSITY BOOKSTORES

Final Report on the Reading Research Project

To: Participating teachers and administrators, Granville Elementary School
From: Esther Thorson, Assistant Professor, Denison University

The present report summarizes the results of four experiments that have been completed since the last report. As pointed out in previous reports, experimental psychologists frequently have shown that poor readers do processing of simple discriminations as accurately as do good readers (e.g., Black, 1973, Leslie & Calfee, 1971). All of the studies summarized here show that poor readers do perform nearly as accurately as do good readers--but they do so with invariably a much slower reaction time. Samuels (1973) suggests that most teachers themselves stress accuracy, but do not stress speed. Might it not be, however, that speed, at least on the very simple tasks used in the present research, is essential to eventual efficient reading? This seems reasonable in light of the fact that reading itself must be carried out fairly quickly, and certainly all the component procedures involved in reading must go on very quickly, even "automatically" (or without conscious attention). Each of the four studies described below show that poor readers are simply not developing the speed that good readers in equivalent grades are demonstrating. In one task, in fact, there are increasing differences in speed across first, second, and third grades.

Experiment 1 presented children with four tasks. First, they were to press a response key if the word "fun" occurred, but not if "bun," "fan," or "fur" appeared. The three "catch" words insured that the children had to look at every letter of the word before responding. The second task was to respond if f appeared, not if b appeared. The third task involved responding to u, not a; and the fourth involved responding to n, not r.

It has been shown that adults can process a three-letter word as quickly as they can process the most difficult component letter. As shown in Figure 1, good readers closely approximate this attribute of adult performance by third grade. Poor readers, however, do not. First grade poor readers who especially long reaction times to the word.

Experiment 2 presented good and poor readers with three letter-discrimination tasks (E-B, Z-V, N-K) each of which appeared in three contexts: (1) the letter presented singly; (2) the letter presented in a word; and (3) the letter presented in a three-word phrase. Adults show equal reaction times at least to single letters and letters appearing in words (Thompson & Massaro, 1973). It was hypothesized, however, that since poor readers showed relatively slow reaction times to the word in Experiment 1, they would be negatively affected by contexts (2) and (3) in the present study. As shown in Figures 2 and 3, this hypothesis was supported, although only for first graders. This means, then, that picking out a single letter from a word is not difficult for poor readers, at least in Grades 2 and 3. Instead, the problem is "putting the letters into word" as required in Experiment 1 that is producing the slowness in processing whole words.

Experiment 3 produced perhaps the most surprising results. Again, good and poor readers were tested. The task was a simple one where the child was asked to press a response key if the letter name he heard was the same as a letter simultaneously presented visually to him. Although seemingly the simplest possible auditory-visual integration task, it has not previously been tested.

As shown in Figure 4, poor readers were at all three grade levels slower than good readers. There was no statistically significant change over grade in the reaction times of either good or poor readers, but the difference in the two groups actually increased across the three grades. In Grade 1, poor readers averaged a reaction time 124 msec. slower than good readers. In Grade 2 the difference increased to 252 msec., and in Grade 3 the difference was 281 msec. Both good and poor readers showed nearly perfect accuracy on the task.

Experiment 4 examined reaction times in two matching tasks and two "preparational switching" tasks. In the letter-matching task, the child was presented on most trials with two letters side by side. If the letters were the same the child was to press a response key. If the letters were different, no response was required. On random trials, however, a three-letter word appeared beside a line drawing. If the word named what was drawn, a response was again required. In the "meaning" match trials, the procedure was reversed. Usually a word appeared beside a line drawing. On random trials two letters appeared. The procedure was carefully explained to the child before he was tested.

There were essentially four tasks, then, in the present study, and all seem closely related to those that have to occur in the process of learning to read. Letter discrimination must occur; matching a "meaning" to a word must occur; and frequently the young reader must switch from letter to meaning levels and back again.

The results are shown in Figure 5. Poor readers are only slightly slower than good readers in matching letters when prepared to do so (letters-preparation trials), but are considerably slower in matching letters when not prepared for that task (letters-switch trials). These differences are especially great for first graders. For meaning matches, poor readers are much slower than good readers when prepared for the task, and that difference increases slightly when they are not prepared for the task. Again, first grade poor readers show much more difficulty with the task than do any other groups.

Taken together, what main generality can be drawn from these studies? Probably the most important point is that of the lack of automaticity in processing simple perceptual discriminations shown by poor readers. Again, automaticity is defined as the ability to perform two or more processing tasks simultaneously, without any lessening of speed or accuracy. Experiment 1 showed that good readers come close to performances indicating that they can process three letters (in a word) simultaneously without decrease in accuracy or increase in speed. Poor readers show much further removed approximations to automaticity performances. Experiment 4 looked at automaticity in a different way, but again demonstrated its lack in poor readers. LaBerge (1973) pointed out in a recent study that automaticity is difficult to demonstrate for adults in simple discriminations. They can discriminate, for example, "new" letters (e.g., ⊟ ,↗) as quickly as alphabet letters. But in the switching task, as used here in Experiment 4, the new-letter discriminations take much longer than alphabet-letter discriminations. Both good and poor readers (except first grade poor readers) showed in Experiment 4 close approximations to automaticity responses for letter matches, but much less close approximations to automaticity responses for meaning matches. Again, poor readers were the furthest removed from automaticity responses.

It seems, in view of this kind of finding, that perhaps more emphasis should be placed on overtraining (Samuels, 1973). This means that, especially for poor readers, training should go on not just for accuracy, but initially for accuracy, and then continued training for speed. Every experiment performed in the present series supports that notion that on simple, basic perceptual discrimination tasks, poor readers are fairly accurate, but usually very slow. Hopefully increase in speed of processing on simple, component tasks related to reading will help poor readers move toward more efficient and confident reading skills.

References

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